THE USE OF LOCKS IN PHYSICAL CRIME PREVENTION

National Crime Prevention Institute

James M. Edgar
William D. McInerney
Revised by Joe A. Mele

Butterworths

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Butterworths
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Preface

Crime prevention is an alternative method of crime control. Citizens' associations, community groups, private individuals and formal law enforcement organizations have all found that a crime prevention program aimed at limiting criminal opportunity is a viable and effective means of decreasing crime—a means that can involve the entire community, rather than just selected portions of it.

The National Crime Prevention Institute has been involved in crime prevention education and research since 1971. Over 21,000 students from all 50 states and 33 foreign countries have attended NCPI classes and seminars. Most of these graduates have returned to their communities, organizations and institutions to organize local crime prevention programs and teach crime prevention.

One factor which has seriously retarded the spread of crime prevention information has been the lack of concise, comprehensive textual material. The few that do exist are rather narrowly focused on industrial and commercial security problems rather than on physical crime prevention as a whole. For this reason, NCPI has authored this monograph which addresses a particular area of crime prevention. The material is presented in layman's language and does not require an extensive background in security

or crime prevention. However, the technological detail contained in the monograph will be of use to professionals in the field.

This monograph is the first of a series of supplements to the NCPI book, *Understanding Crime Prevention.*

Acknowledgments

I would be remiss if I did not acknowledge the efforts of Mr. William D. McInerney and Mr. James M. Edgar who wrote the original publication, *The Use of Locks in Physical Crime Prevention* in 1976.

This monograph is a revision of their material. Some locking devices have been deleted, new devices have been added. While revising the text, I found much evidence of their dedication to the concepts of crime prevention. I could not improve on that philosophy.

Joe A. Mele, MS, CPP
National Crime Prevention Institute
Louisville, Kentucky

Introduction

A lock is a mechanical or electrical device used to restrict ingress, egress or operation to persons having the proper key, code or combination. Ordinarily, a lock is used to fasten two or more objects together, limiting or entirely preventing their relative movement (e.g., a locked door in a door jamb). A lock can be distinguished from other types of more permanent fasteners used to fix two or more objects together (such as nails, screws, bolts, etc.) in that it can be unsecured quickly and easily by an authorized person with the key, code or combination. It also differs from a simple latch in that a latch requires no key or combination to operate and can, therefore, be opened by anyone who is physically capable of doing so (turning a doorknob to open the door, for example). Common applications are door and window locks, locks on drawers, cabinets, desks, strong boxes, and other physical openings which restrict ingress or egress; and ignition locks on automobiles and switch locks on electrical equipment which are designed to restrict operation.

The lock is the most widely used security device. Wherever people have an interest in securing their persons or property against intruders, some sort of locking devices have been developed

and used. Crudely designed but intricately fashioned locks of hardwood using keys and tumblers have been traced as far back as the ancient Egyptians. The Greeks also made a number of notable contributions to the development of the lock. But the real innovators of the ancient world were the Romans. Roman craftsmen made their locks out of bronze and iron rather than wood for added security. They introduced the spring-loaded bolt, padlocks and paracentric keyways—devices which are still being used today. Their most important contribution, however, was the warded lock which was the most secure locking device available until the middle of the eighteenth century.

Much of this expertise was lost after the German invasions of the Roman Empire, and was not to be regained until the nations of Europe had achieved a degree of stability which made commerce once again possible and locks again necessary to protect the wealth of merchants and royalty. The locks of this period were still the warded type. They eventually became very complex and intricate. Most required a very large, heavy key to reach and throw a cumbersome bolt. For increased security many systems used hidden keyways and multiple keys to operate extremely complicated mechanisms. Despite these refinements, the degree of protection afforded by warded locks remained severely limited.

No breakthroughs were made in lock design until 1772 when the lever tumbler lock was introduced. This lock depended on movable internal barriers (lever tumblers) for security rather than on fixed wards. It was many times more secure than the warded lock and used a much smaller, more convenient key. A great many improvements were made to lever systems over the years. Some were so secure that for many years they could not be picked even by the companies that manufactured them. The lever tumbler system is still widely used, and is the basis for a number of modern high-security locking systems.

The Industrial Revolution and the rapid evolution of a machine tool industry was the prerequisite for the next major advance in locking technology.

Linus Yale, Jr. is credited with inventing the detachable pin tumbler cylinder lock which he introduced in 1861. The pin tumbler lock was the first locking mechanism with some security which could be mass produced easily and inexpensively using ordinary factory tools. It is currently the most widely used locking

system in the United States. It is also the basis for many of the special mechanical high security locks that have been developed during recent years. Its only competition in frequency of utilization is the disc or wafer tumbler lock which was developed during the early part of the twentieth century specifically for use in automobiles. Just as the development of the pin tumbler required the emergence of a machine tool industry, the disc tumbler depended on rapid advances made by automobile manufacturers in die casting, which is the basic process by which it is produced. Although disc tumbler mechanisms are widely employed in other applications, most will still be found as ignition and door locks on automobiles.

Warded mechanisms and systems using lever, pin or disc tumblers are the basis for most of the locks currently used in the United States. The common feature of these devices is that they are *key-operated*. Other devices which do not require a key have been developed, however. These include *combination locks*, *electro-mechanical locks*, and *electronic locks*. Electro-mechanical and electronic systems are usually found in special and high-security applications. Since they are seldom encountered, they will not be treated here.

Key-operated and combination locks operate on purely mechanical principles. These are the types of locks ordinarily found in residences and light commercial buildings.

LOCK TERMINOLOGY AND COMPONENTS

The effectiveness of any locking system depends on a combination of interrelated factors that are involved in the design, manufacture, installation and maintenance of the system. A security specialist needs to understand the weaknesses and strengths of the various systems, and know how each must be used to achieve maximum benefit from its application. This requires a thorough understanding of the inner workings of the various types of locks. It is not sufficient to know what in someone's opinion is a "good lock." A good lock today may not be as good tomorrow as technology improves and manufacturers alter their designs and production techniques. A lock that is excellent in some applications may

be undesirable in others. A knowledge of the basic principles of locking systems will enable a security specialist to evaluate any lock he may encounter and determine for himself its quality and its effectiveness in a particular application. Our purpose here is to present the minimum necessary material which will enable you to understand the proper use of locks as security devices.

1

Key- and Combination-Operated Mechanisms

A key-operated mechanical lock uses some sort of arrangement of internal physical barriers (wards, tumblers) which prevent the lock from operating unless they are properly aligned. The key is the device used to align these internal barriers so that the lock may be operated. The lock itself is ordinarily permanently installed. The key is a separate piece which is designed to be removed from the lock to prevent unauthorized use.

Four types of key-operated locks will be introduced in this section: warded, disc or wafer tumbler, pin tumbler, and lever. These are the types of key-operated locks most commonly found in the United States.

WARDED LOCKS

A warded system uses fixed obstructions (*wards*) projecting from the inside of the lock housing (*internal wards*) or from the side of the keyhole (*keyway wards*) which block the entrance and/or the rotation of all keys except the proper *change key* for that lock or the *master key* designed to operate locks of that series (Figure 1-1).

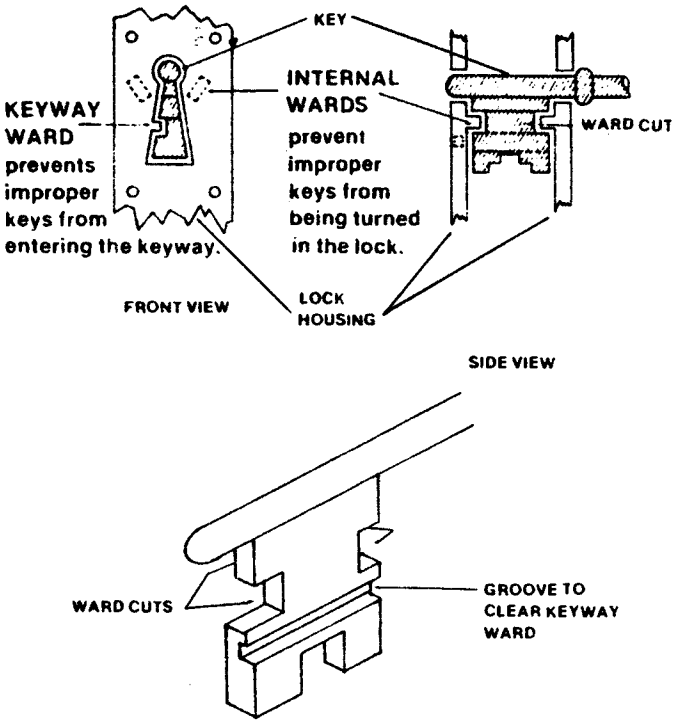

KEY
INTERNAL WARDS prevent improper keys from being turned in the lock.
KEYWAY WARD prevents improper keys from entering the keyway.
WARD CUT
FRONT VIEW
LOCK HOUSING
SIDE VIEW
WARD CUTS
GROOVE TO CLEAR KEYWAY WARD

Figure 1-1. Warded lock.

Wards are also designed to restrict the use of manipulative tools such as lock picks.

Warded locks are operated by *warded keys* which have grooves, notches, or cuts in their bits (Figure 1-2) designed to clear the warding in the lock, permitting them to enter the keyway and rotate the lock assembly. These cuts are called *warded cuts.* Old fashioned warded keys were usually of either the *bit key* or *barrel key* type, which are illustrated in Figure 1-3. Warded locks may also be operated by a *master key* which has a large part of the bit cut away so that it can be used to operate all warded locks of a particular model or series.

Warded mechanisms are the oldest, simplest and least secure of all basic key-operated locking systems currently in use. It is the only system using fixed obstructions as the sole internal barrier so that any modified key or other tool which will clear these

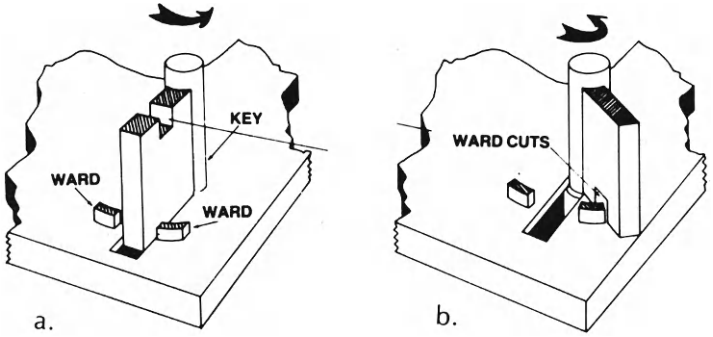


Figure 1-2. a. When an improper key is inserted in the lock, the wards prevent it from turning; b. When the proper key is used, the ward cut in the key allows it to clear the ward and operate the lock.

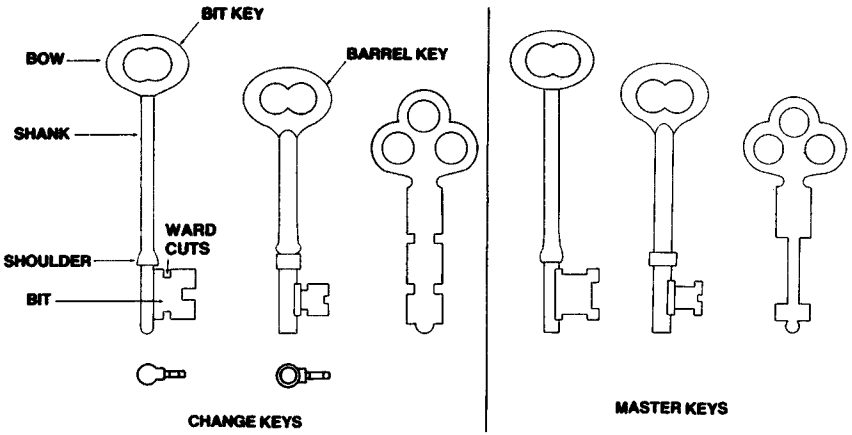


Figure 1-3. Change keys and master keys for warded locks.

obstructions can operate the lock. A simple piece of bent stiff wire is often all that is needed to open a warded mechanism. No matter how intricate the system of fixed wards may be, they can still be made to leave a mark on a suitable prepared key blank which will allow anyone of limited skill to make a key which will operate the lock. The process is simplified by the fact that the depth of the cuts in a warded key is not critical. As long as they are deep enough to clear the wards, the key will work. If they are

deeper than necessary, the key will work just as well (Figure 1-4), which is not true of most locking systems using movable internal barriers.

Warded locks are often found on houses in the oldest part of most cities. It is common in these areas to find that the crime problem is acute and that reasonable security is required. Unfortunately, it is also these parts of the city which are inhabited by its lower income residents who can seldom afford the expense of replacing or supplementing warded systems with more secure tumbler locks. Nevertheless, the use of warded locks on exterior doors should be discouraged. When these are found, the resident should be encouraged to use a supplementary tumbler device.

Other common applications of warded mechanisms are in cabinet and drawer locksets, luggage locks, and inexpensive padlocks (Figure 1-5). In these applications, warded locks should be considered privacy locks rather than locks offering any real security. If reasonable security is a requirement, they should be replaced.

Wards are also used in conjunction with tumblers to increase the security of tumbler devices. Ordinarily these are placed in the keyway (*keyway wards*) to prevent the entry of improper keys.

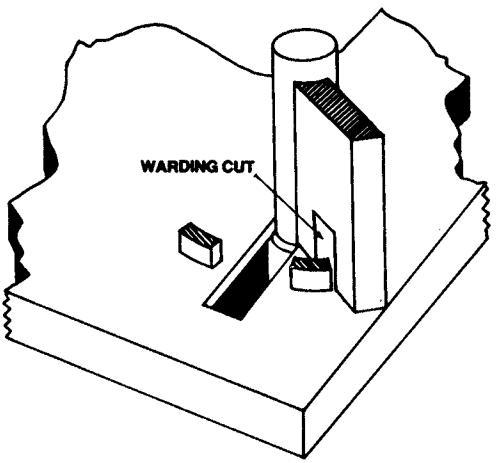


Figure 1-4. The ward cut here is much deeper than necessary. The key will nevertheless operate the lock. This is one of the features which contributes to their relative lack of security.

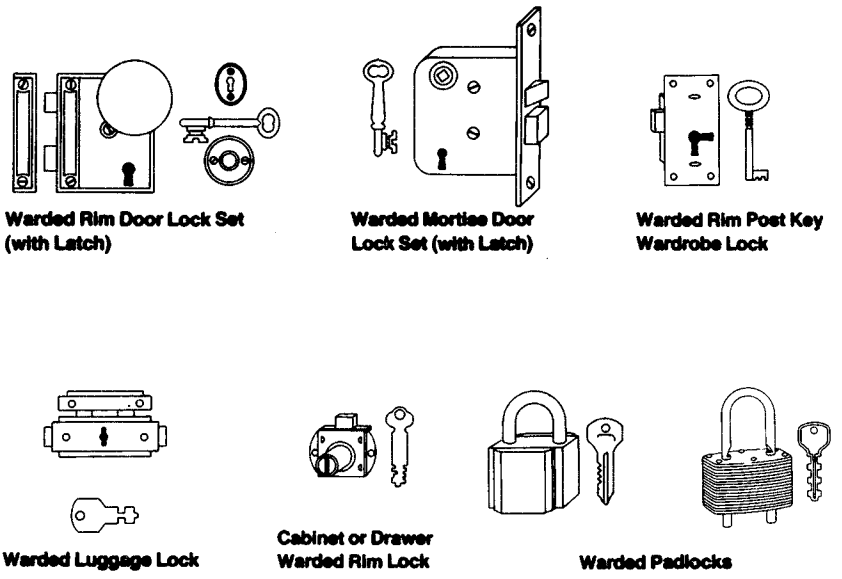

Warded Rim Door Lock Set (with Latch)
Warded Mortise Door Lock Set (with Latch)
Warded Rim Post Key Wardrobe Lock
Warded Luggage Lock
Cabinet or Drawer Warded Rim Lock
Warded Padlocks

Figure 1-5. Typical warded locks.

Some tumbler devices, however, use wards as internal barriers in addition to the movable elements (*tumblers*). The presence of wards in these devices does not make them warded locks. The distinguishing feature of warded mechanisms is that they have *no* movable internal barriers at all and use fixed wards as their sole security element. When tumblers are also present, providing the major security barrier of the mechanism, the lock is considered a tumbler mechanism.

TUMBLER MECHANISMS

A tumbler mechanism is any lock mechanism having movable, variable elements (*the tumblers*) which depend on the proper key (or keys) to arrange these tumblers into a straight line permitting the lock to operate. The tumbler, which may be a disc, a lever or a pin, is the lock barrier element which provides security against improper keys or manipulation. The specific key which

operates the mechanism (which is called the *change key*) has a particular combination of cuts or bittings which match the arrangement of the tumblers in the lock. The combination of tumblers can usually be changed periodically by inserting a new tumbler arrangement in the lock and cutting a new key to fit this changed combination. This capability provides additional security by protecting against lost or stolen keys.

Tumbler mechanisms and the keys which operate them are produced to specifications which vary with each manufacturer and among the different models produced by each manufacturer. These specifications are known as the *code* of the lock mechanism. The coding for each mechanism provides specifications for both the fixed and variable elements of the lock assembly. The relationship between these elements is shown diagrammatically in Figure 1-6. Fixed specifications include:

- the dimensions of each of the component parts of the lock and the established clearances between each part (e.g., the size and length of the key must match the size and depth of the keyway).
- the spacing of each tumbler position and their relation to each other (Figure 1-7).
- the depth intervals or increments in the steps of each cut or bitting (Figure 1-8).

The relationship between the dimensions of the tumblers and the bitting on the key is shown for a typical pin tumbler mechanism in Figure 1-9. These codes provide a locksmith with the dimensions and specifications they need to produce a specific key to operate a particular lock or to key additional locks to the combination of a particular key.

The different arrangements of the tumblers permitted in a lock series are its *combinations*. The theoretical or mathematical number of possible combinations available in a specific model or type of lock depends on the number of tumblers used and the number of depth intervals or steps possible for each tumbler. You can determine the combinations possible for a typical five-pin tumbler mechanism yourself by referring to Figure 1-6. If the lock had only one tumbler which could be any of the ten lengths depicted, the lock would have a total of ten (10^1) combinations.

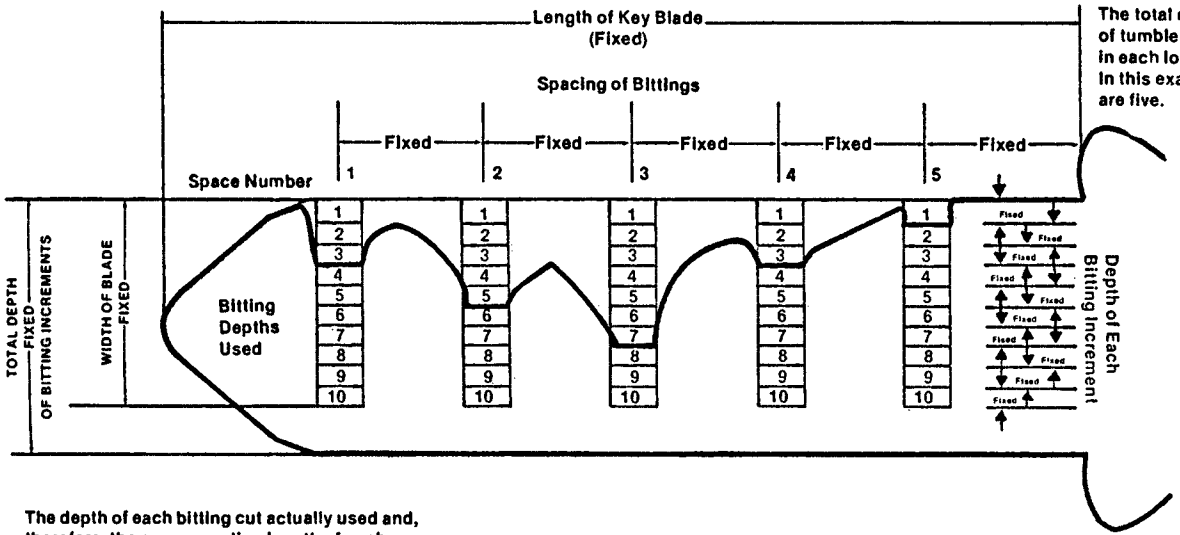

Length of Key Blade
(Fixed)
The total number of tumblers available in each lock is fixed. In this example there are five.
Spacing of Bittings
Fixed
Fixed
Fixed
Fixed
Fixed
Space Number
1
2
3
4
5
TOTAL DEPTH FIXED
OF BITTING INCREMENTS
WIDTH OF BLADE FIXED
Bitting Depths Used
Depth of Each Bitting Increment
The depth of each bitting cut actually used and, therefore, the corresponding length of each tumbler is variable. Depths from one to ten for each space could be used in this example. The combination used for this key are (reading from right to left): 1 3 7 5 3.
The total number of bitting cuts available is fixed as is the depth of each cut.

Figure 1-6. The relationship between the fixed and variable elements of a tumbler mechanism.

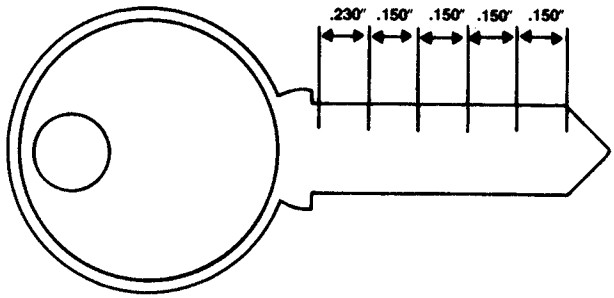


Figure 1-7. The spacing or position of each cut on the key is a fixed dimension corresponding to the position of each tumbler in the lock.

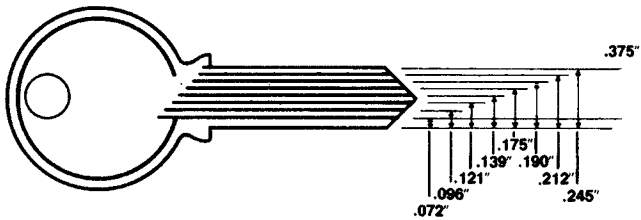


Figure 1-8. The depth interval (increment) of the steps of each cut or bitting is a fixed dimension.

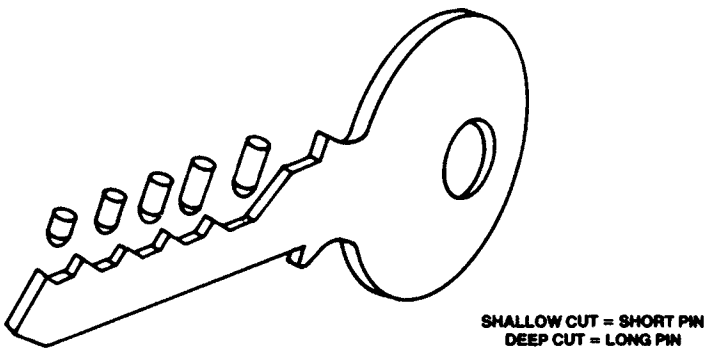


Figure 1-9. The depth of each cut corresponds to the length of each tumbler in the lock.

If it had two tumblers, it would have a possible total of 100 (10 × 10 or 10^2) combinations. With three tumblers 1000 (10 × 10 × 10 or 10^3) combinations are possible. If all five tumblers were used, the lock would have a possible 100,000 (10^5) combinations. The number of mathematically possible combinations for any lock can be determined by this method.

Due to a number of mechanical and design factors, however, not all of these theoretically possible (implied) combinations can actually be used. Some combinations allow the key to be removed from the lock before the tumblers are properly aligned (shedding combinations); something that should not be possible with a properly combinated tumbler lock. Others, such as equal-depth combinations are avoided by the manufacturers. Some combinations result in a weakened key which is prone to break off in the lock. Others are excluded because the space from one cut in the key erodes the space or positioning of adjacent cuts. The combinations which remain after all of these possibilities have been removed are called *useful combinations*. The useful combinations which are actually employed in the manufacture of the lock series are the basis for the *bitting chart* which lists the total combinations used in a particular type or model of lock. When other factors are equal, the more combinations that can actually be used in a lock, the greater its security. Total useful combinations range from one for certain types of warded locks to millions for a few high-security tumbler key mechanisms.

Disc or Wafer Tumbler Mechanisms

Disc tumbler mechanisms consist of three separate parts: the keys, the cylinder plug and the cylinder shell (or housing) (Figure 1-10a-d). The plug contains the tumblers which are usually spring-loaded flat plates which move up and down in slots cut through the diameter of the plug (Figure 1-10b). Variably dimensioned key slots are cut into each tumbler (Figure 1-10d). When no key is inserted or an improper key is used, one or more tumblers will extend through the sides of the plug into either the top or bottom locking grooves cut into the cylinder shell, firmly locking the plug to the shell. This prevents the plug from rotating in the shell to operate the lock. The proper change key has cuts or bittings to

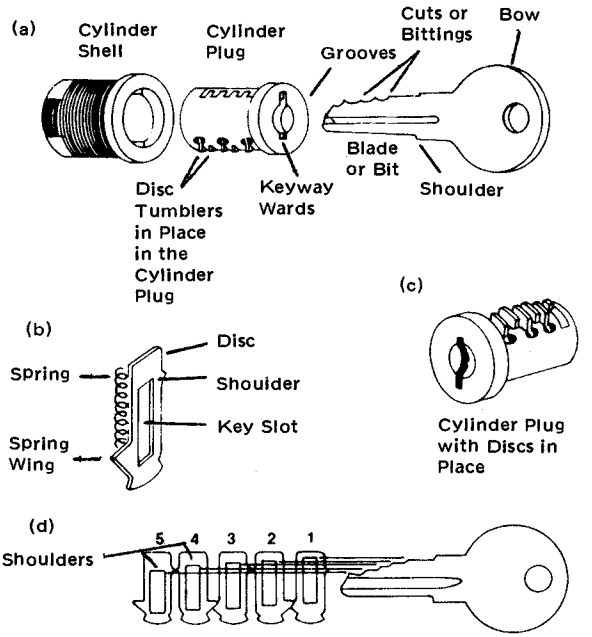


Figure 1-10. The key slots in the discs correspond to the cuts or bittings cut in the key. Note how each cut in the key will align its corresponding disc in a straight line with the others.

match the variations of the tumblers. When inserted the key aligns all of the tumblers in a straight line at the edge of the cylinder plug (the *shear line*) so that no tumbler extends into the shell. This permits the plug to rotate (Figure 1-10d and Figure 1-11).

Disc mechanisms generally provide only moderate security with limited key changes or combinations. Depth intervals commonly used are from .015 to .030 inches which permit no more than four or five depths for each tumbler position. Some models used as many as six tumblers. The more commonly found five-tumbler mechanism which allows five depth increments for each tumbler position would have a maximum of 3.125 implied combinations. The number of useful combinations would, of course, be considerably fewer for the reasons indicated earlier. Some added security is provided by the common, although not universal, use of warded and paracentric keyways which help protect against incorrect keys and manipulation. Nevertheless, most of these locks may be manipulated or picked fairly easily by a person with limited skills.

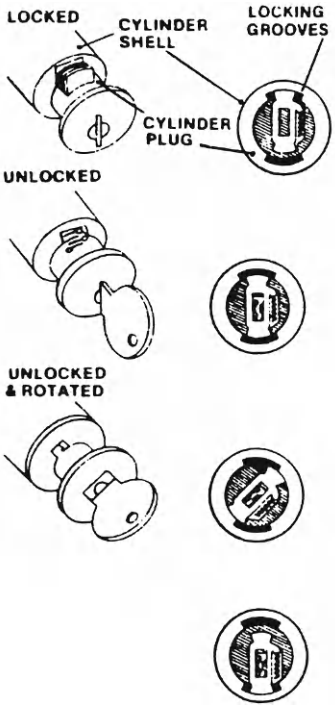


Figure 1-11. Operation of a disc tumbler mechanism. Without the key the disc tumblers are pushed into the locking groove cut into the cylinder shell. This prevents the cylinder plug from rotating in the shell to operate the lock.

When the proper key is inserted, the discs are aligned in a straight line at the edge of the cylinder plug. This is known as the shear line.

Once the discs are aligned at the shear line, the cylinder plug can be rotated in the shell to operate the lock.

Note that if an improper key is inserted into the lock, the disc can be forced past the edge of the plug. When this happens, the other end of the disc enters the locking groove on the other side of the shell, preventing the plug from rotating.

In addition, the variations cut into the tumblers can be "sight read" with some practice while the lock is installed. Sight reading involves manipulating the tumblers with a thin wire and noting the relative positions of each tumbler in the keyway. Since each lock has only a limited number of possible tumbler increments, the

correct arrangement of these increments can be estimated with fair accuracy permitting a key to be filed or cut on the spot to operate the lock.

There are a number of variations in the basic disc tumbler mechanism. Some of these modifications are designed to make the lock more secure. Others are to simplify manufacture or to reduce costs. The five principal variations that you are most likely to encounter are presented below.

Double-Sided Keyways. Some mechanisms use double-sided keys which act on tumblers at both the top and bottom of the keyway or alternately the top of one and the bottom of the next tumbler in line (Figure 1-12). Several manufacturers produce models of this lock including the American Lock Company, the Chicago Lock Company and the Illinois Lock Company. Most double-sided mechanisms provide no more security than the ordinary single-sided lock, and may be picked and sight read just as easily.

The Duo Disc Tumbler Mechanism. This mechanism, manufactured by the Illinois Lock Company, uses a double-sided key with a third set of bittings milled into the ribs of the key blank to align a third set of tumblers (Figure 1-13). The additional tumblers possible with this system dramatically increase the number of useful combinations which can be used. One model of the Duo lock is listed by the Underwriters' Laboratory as highly manipulation and pick resistant and considered a high security lock.

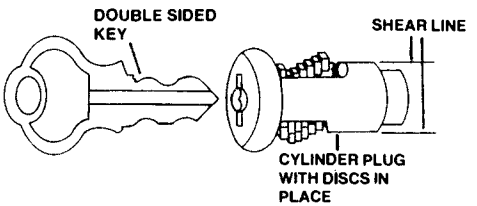


Figure 1-12. Double-sided disc tumbler mechanism. A double-sided mechanism must be sprung in both directions rather than in a single direction. Half of the tumblers shown in this example are sprung in one direction. The remaining tumblers are sprung in the other.

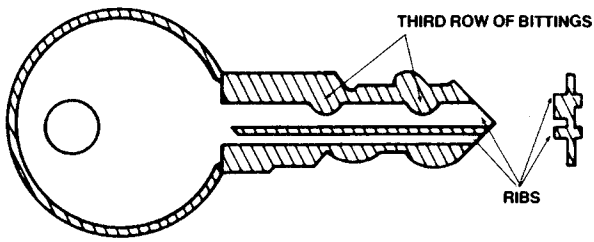


Figure 1-13. The Duo key.

Schlage Cylindrical Disc Tumbler Mechanism. The Schlage Lock Company makes a disc tumbler system using a double-sided key which combines internal wards and disc tumbler elements (Figure 1-14). This lock uses only two tumbler positions, and while the spacing or location of the cuts in the key is important, the depth of the cuts is not. The cuts must be deep enough to allow each tumbler to retract past the outside diameter of the cylinder plug, but the lock will operate if the cuts are deeper than required. The system has limited key changes or combinations and may be manipulated easily. This mechanism is only used in cylindrical (key-in-knob) locksets. It is a very popular builder's hardware item which is commonly found as the primary lock on the exterior doors of houses and apartments.

Sidebar Cylinder. These locks use a single-sided key with disc tumblers and a sidebar element (Figure 1-15). They are made by the General Motors Corporation and have been used on all automobiles of their manufacture since 1937. The tumblers are not very different from conventional disc tumblers, but the operation of the cylinder plug is not controlled directly by the discs themselves. When the proper key aligns the tumblers, notches cut in them permit a sidebar to retract into the cylinder plug, clearing the locking groove in the shell, allowing the plug to rotate. The tumblers do not protrude beyond the cylinder plug as in most conventional disc mechanisms.

This lock has approximately two thousand combinations. Different grooved or milled key blanks are used for ignition and door cylinders in present models so that the door key cannot be used to operate the ignition. This added security feature means that an unauthorized user must circumvent two different locks to

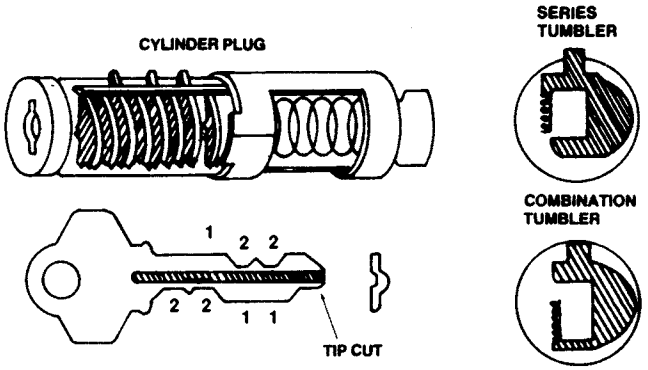


Figure 1-14. Schlage cylindrical disc tumbler mechanism. Each Schlage mechanism is fitted with eight discs. Four of these are combination tumblers, three are series tumblers and the last tumbler in the mechanism is called the master tumbler. The master tumbler acts as a series tumbler in all respects except that it will allow only a properly tipped key to pass. When no key is in the lock, the series tumblers are sprung to extend past the plug and into the locking groove in the shell; the combination tumblers are sprung to retract into the cylinder plug. If an improper key is used, the series tumblers will retract into the plug, but the combination tumblers will be forced into the locking groove.

Only two bitting depths are used on a Schlage key. Cut number 1 is no cut at all—the key is left at full width. All remaining cuts are at the same depth (see diagram above). The number 1 bittings correspond to the location of the series tumblers. The full width of the blade is needed to retract each series tumbler. The number 2 bittings correspond to the combination tumblers. These cuts are to prevent these tumblers from being forced into the locking groove. Since combination tumblers can face either up or down, cuts on the top and bottom of the blade are required depending on which direction the combination tumblers are inserted.

When the properly cut key is used all of the series tumblers (and the master tumbler) will retract into the plug, and no combination tumblers will be forced into the locking groove. This arrangement permits the plug to rotate, operating the lock.

Note that to pick this lock, it is only necessary to retract the series tumblers. Nothing need be done to the combination tumblers which are already retracted.

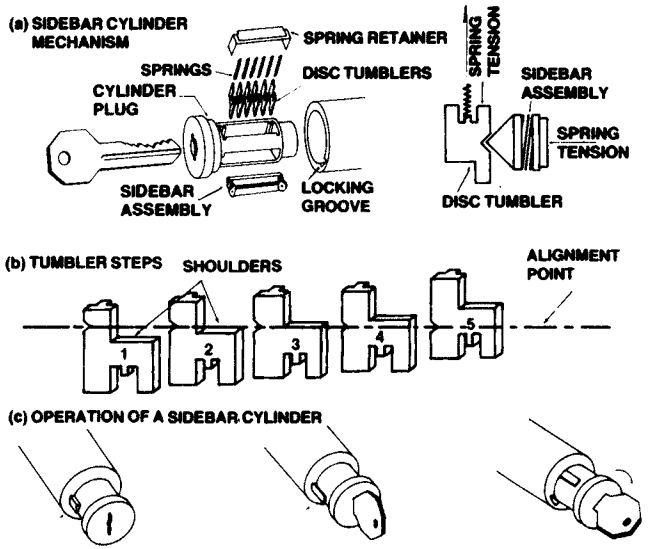


Figure 1-15. Sidebar cylinder mechanism, a and b. In order for the notches to align, permitting the sidebar to retract, each tumbler must be raised to a different height by the bittings on the key. c. Without the key, the notches on the tumblers do not align and the sidebar is extended into the locking groove. With the proper key inserted, the notches on the tumblers are aligned, permitting the sidebar to retract into the plug. The plug can then be rotated to operate the lock.

enter and operate the vehicle. Key blanks have been changed every model year since 1967. The lock is very pick resistant. Most locksmiths will not even attempt to pick a G.M. lock.

The Bell Lock. The Bell lock uses the double grooved key illustrated in Figure 1-16. The tumblers are rectangular bars with protruding stumps or pins in the side of each bar which ride in the groove of the key. The grooves are milled into each side of the key in an irregular pattern. They act just like bitting cuts on a regular key to raise the tumblers to different heights. When the proper key is inserted it intersects the stumps in the sides of the tumbler bars bringing them into alignment along the shear line, allowing the cylinder plug to rotate. These locks use from six to nine tumblers in approximately 2,500 combinations and are

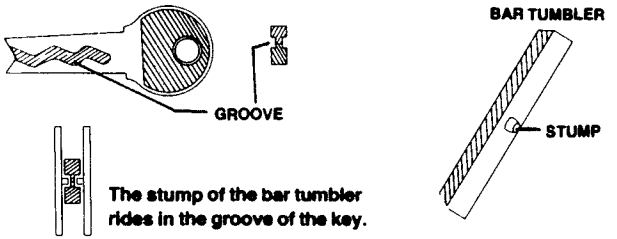


Figure 1-16. Bell lock.

difficult to pick without special tools and skills. Bell locks are designed primarily for use in vending machines, parking meters and similar equipment which is where they are most commonly encountered.

Pin Tumbler Mechanisms

The pin tumbler mechanism is the most common type of key-operated mechanism used in architectural or builders' (door) hardware in the United States. The security afforded by this mechanism ranges from fair in certain inexpensive cylinders with "wide" tolerances and a minimum of tumblers to excellent with several makes of high security cylinders, including those that are listed by Underwriters' Laboratories as manipulation and pick resistant.

The lock operates very much like disc tumbler mechanisms (Figure 1-17). The locking system itself consists of a key, a cylinder plug, and a cylinder shell or housing. Rather than using discs, the mechanism uses pins as the basic interior barrier. Each lock contains an equal number of upper tumbler pins (*drivers*) and lower tumbler pins (*key pins*). The proper key has cuts or bittings to match the length of the lower pins. When it is inserted, the tops of the key pins are aligned flush with the top of the cylinder plug at the shear line (Figure 1-18a). The plug may then rotate to lock or unlock the mechanism. When the key is withdrawn, the drivers are pushed by springs into the cylinder plug, pushing the key pins ahead of them until the key pins are seated at the bottom of the pin chamber. The drivers extending into the plug prevent it from rotating (Figure 1-18b).

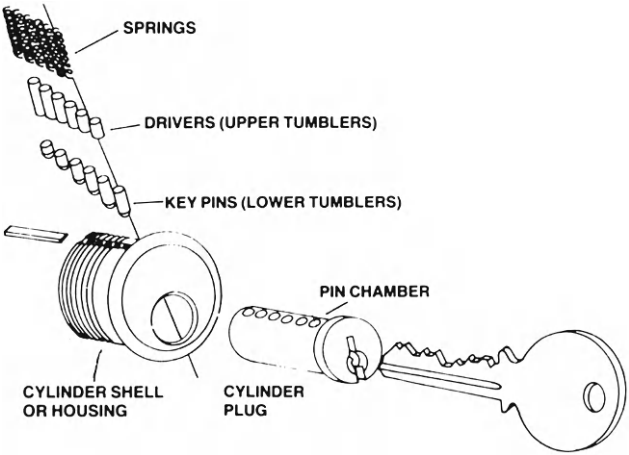


Figure 1-17. Basic pin tumbler cylinder lock mechanism.

If an improper key is inserted, at least one key pin will be pushed into the shell, or one driver will extend into the plug. In either case, the pin extending past the shear line binds the plug to the shell. One or more key pins may be aligned at the shear line by an incorrect key, but all will be aligned only when the proper key is used (Figure 1-18c).

Depth intervals commonly used for pin tumbler cylinders vary from .0125 to .020 inches. These intervals allow between five and ten depths for each tumbler position. The number of pins used ranges from three to eight—five or six being the most common number. Maximum useful combinations for most standard pin tumbler cylinders (assuming eight tumbler depth increments) are as follows:

3 pin tumblers	=	approximately 130 combinations
4 pin tumblers	=	approximately 1,025 combinations
5 pin tumblers	=	approximately 8,200 combinations
6 pin tumblers	=	approximately 65,500 combinations

These estimates assume that the useful combinations amount to no more than 25% of the mathematically possible combinations. Many common pin tumbler locks use less than eight increments, so the number of useful combinations for a specific lock may be

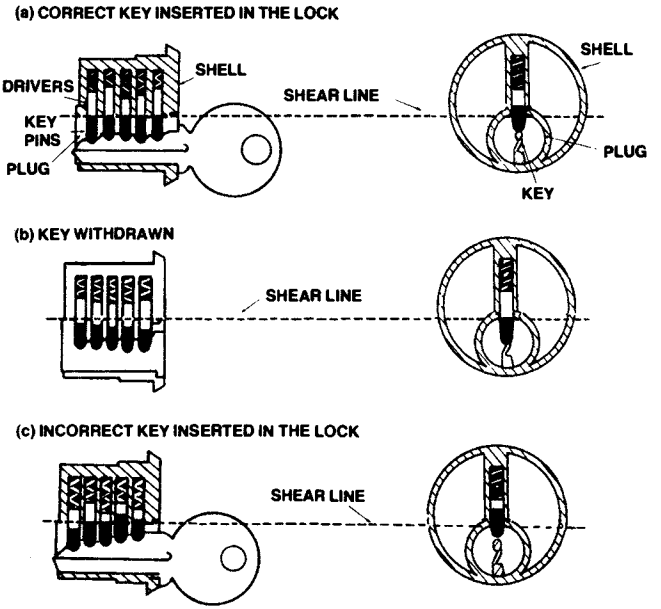


Figure 1-18. Operation of a pin tumbler cylinder mechanism. a. When the correct key is inserted, the bittings in the key align the tops of the lower tumblers (key pins) with the top of the cylinder plug at the shear line. The plug may then be rotated in the shell to operate the lock. b. When the key is withdrawn, the springs, push the upper tumblers (drivers) into the cylinder plug. With the pins in this position, the plug obviously cannot be turned. c. When an incorrect key is used, the bittings will not match the length of the key pins. The key will allow some of the drivers to extend into the plug, and some of the key pins will be pushed into the shell by high cuts. In either case, the plug cannot be rotated. With an improper key, some of the pins may align at the shear line, but only with the proper key will all five align so that the plug can turn.

much lower than the figures given above. Master keying will also greatly reduce the number of useful combinations.

Pin tumbler mechanisms vary greatly in their resistance to manipulation. Poorly constructed, inexpensive cylinders with "wide" tolerances, a minimum number of pins and poor pin chamber alignment may be manipulated quickly by persons of limited ability. Precision-made cylinders with close tolerances, a maximum number of pins and accurate pin chamber alignment may resist picking attempts even by experts for a considerable time.

Most pin tumbler lock mechanisms use warded keyways for additional security against incorrect keys and manipulation. The wards projecting into the keyway must correspond to grooves cut into the side of the key, or the key cannot enter the lock. When the wards on one side of the keyway extend past the center line of the key, and wards on the other side also extend past the center line, this is known as a *paracentric* keyway (Figure 1-19). While warded keyways are commonly used on most pin tumbler mechanisms, paracentric keyways are usually restricted to the better locks. They severely hinder the insertion of lockpicks into the

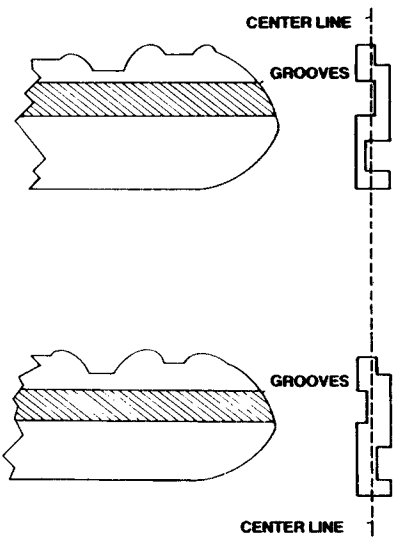


Figure 1-19. Milled warded and paracentric keys. *Milled paracentric key.* Note that the grooves must extend past the center line of the key in order to clear the wards in the keyway. The shape of this keyway makes it more difficult to maneuver picks inserted into the lock mechanism.

Warded or milled key. The grooves in the key do not quite extend to the center line. This type of keyway is not as resistant to the manipulation of lockpicks.

Both deep and shallow grooves may be incorporated into the same key to pass deep and shallow wards in the keyway.

mechanisms and the ability of the manipulator to maneuver the pick once it is inserted.

Modifications have been made to the drivers in better locks to provide increased security against picking (Figure 1-20). The usual modified shapes are the *mushroom* and the *spool*. Both of these shapes have a tendency to bind in the pin chamber when picking is attempted making it more difficult to maneuver them to the shear line. To be consistently successful in picking pin tumbler cylinders with either type of modified driver, special techniques must be used.

There are a number of variations of the pin tumbler cylinder on the market. One which is seeing increasingly widespread use is the *removable core cylinder* (Figure 1-21). These were originally produced by the Best Universal Lock Company whose initial patents have now expired. Most major architectural hardware manufacturers now have them available in their commercial lock lines. This type of cylinder uses a special key called the *control key* to remove the entire pin tumbler mechanism (called the *core*) from the shell. This makes it possible to quickly replace one core with another having a different combination and requiring a different key to operate. Because of this feature, removable core cylinders are becoming increasingly popular for institutional use, and use in large commercial enterprises where locks must be changed often.

Removable core cylinders do not provide more than moderate security. Most systems operate on a common control key, and possession of this key will allow entry through any lock in the system. It is not difficult to have an unauthorized duplicate of the control key made. If this is not possible, any lock, particularly a padlock, of the series may be "borrowed" and an unauthorized

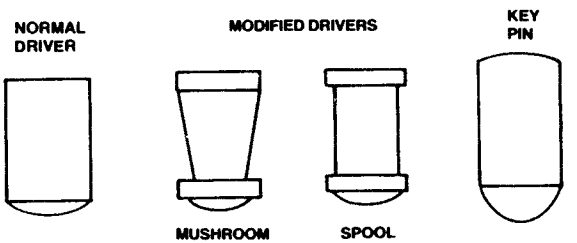


Figure 1-20. Pin tumbler modification.

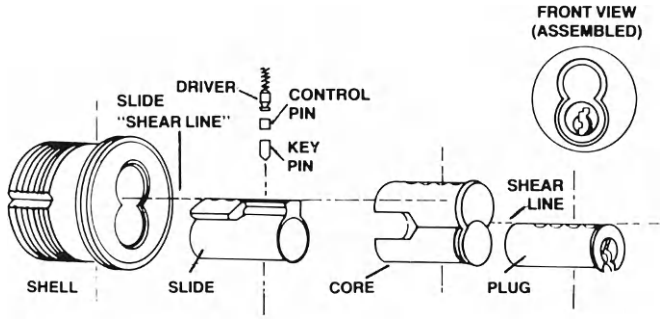


Figure 1-21. Removable core pin tumbler cylinder mechanism. A removable core system has two shear lines, one at the top of the plug as in other systems, and another at the top of the slide. When the correct change key is inserted it aligns the key pins at the top of the plug permitting the plug to be rotated in the core. When the control key is inserted, it aligns the control pins at the top of the slide shear line. This permits the slide to be rotated 20 degrees which unlocks the core. The core (including the plug, slide, and all pins and springs) can then be removed with the key and a new core inserted.

control key made. Once the core is removed from a lock, a screwdriver or other flat tool is all that is necessary to operate the mechanism. Additionally, the added control pins increase the number of shear points in each chamber, thus increasing the mechanism's vulnerability to manipulation.

Another variation that has been in widespread use for many years is *master keying*. Almost any pin tumbler cylinder can be easily master keyed. This merely involves the insertion of additional tumblers called *master pins* between the drivers and key pins. These master pins enable a second key, the *master key*, to operate the same lock (Figure 1-22). Generally, an entire series of locks is combinated to be operated by the same master key. There may also be levels of master keys including submasters which open a portion, but not all, of a series; master keys which open a larger part; and grand masters which open the entire series. In very involved installations, there may even be a fourth level (great grand master key).

There are a number of security problems with master keys. The most obvious one is that an unauthorized master key will permit access through any lock of the series. Less obvious is the

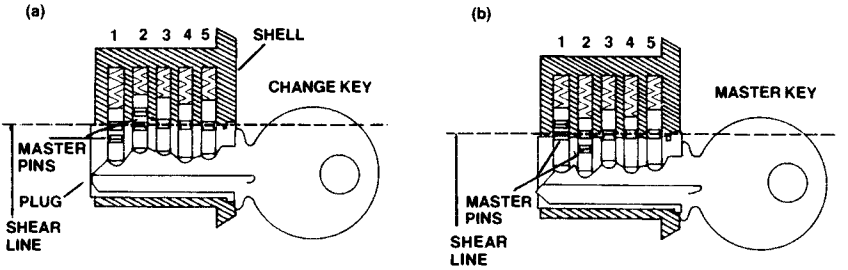


Figure 1-22. Master-keyed pin tumbler cylinder mechanism. a. This is a simple master-keyed system using master pins in the first and second tumbler positions. When the change key is inserted, note that the top of the first master pin aligns with the top of the cylinder plug. The remaining positions show the key pins aligned with the top of the plug. This arrangement permits the plug to turn. b. With the master key inserted, the first position aligns the top of the key pin with the cylinder plug. The master pin is pushed further up the pin cylinder. The second position shows the master pin aligning at the top of the plug. The master pin has dropped further down the pin hole in the plug. The remaining three positions are unchanged. This arrangement also allows the plug to rotate.

fact that master keying reduces the number of useful combinations that can be employed since any combination used must not only be compatible with the change key, but with the second, master key. If a sub-master is used in the series, the number of combinations is further reduced to those which are compatible with all three keys. If four levels of master keys are used, it should be obvious that the number of useful combinations becomes extremely small. If a large number of locks are involved, the number of locks may exceed the number of available combinations. When this occurs, it may be necessary to use the same combination in several locks which permits one change key to operate more than one lock (*cross keying*). This creates an additional security hazard.

One way of increasing the number of usable combinations and decreasing the risk of corss keyiny is to use a *master sleeve* or ring. This sleeve fits around the plug, providing an additional shear line similar to the slide shear line in a removable core system. Some of the keys can be cut to lift tumblers to sleeve shear line, and some to the plug shear line. This system, however, requires

the use of more master pins. Any increase in master pins raises the susceptibility of the lock to manipulation since the master pins create more than one shear point in each pin chamber, increasing the facility with which the lock can be picked.

Thus, while master-keyed and removable core systems are necessary for a number of very practical reasons, one should be aware that they create additional security problems of their own.

The basic pin tumbler mechanism has been extensively modified by a number of manufacturers to improve its security. Five of these high-security mechanisms will be briefly introduced in this section. The common features of high-security pin tumbler cylinder mechanisms are that they are produced with extremely close tolerances and that they provide a very high number of usable combinations. Additional security features include the use of very hard metals in their construction to frustrate attacks by drilling and punching.

The Sargent "Keso" Mechanism. This lock, manufactured by the Sargent Company, provides a high degree of security against surreptitious entry. It uses the pin tumbler principle, but in an unconventional cylinder design (Figure 1-23). Rather than using five or six pins in a single row, it uses 12 pins, four in each of three rows which are located radially approximately 90 degrees from each other. The Keso key is also quite different from other pin tumbler keys. Rather than using cuts just on the top of the blade, the Keso key, which is six sided, has milled indentations on all six sides which match the tumblers in the lock. In use only three sides actually contact the tumblers at any one time. The milling on all six sides is to permit the key to be inserted in the lock without regard to direction.

Spacings on the Keso key are not, like ordinary keys, in fixed positions. Therefore, an infinite number of tumbler positions are possible. The actual positions of the indentations on a working key are determined by computer in a manner that prevents any one indentation from interfering with the rest. Keso keys are strictly regulated by the factory. The keys cannot be duplicated by local locksmiths on standard key duplicating machines. All duplicates must be made by special request at the manufacturer's plant. Even the sale of key blanks is restricted.

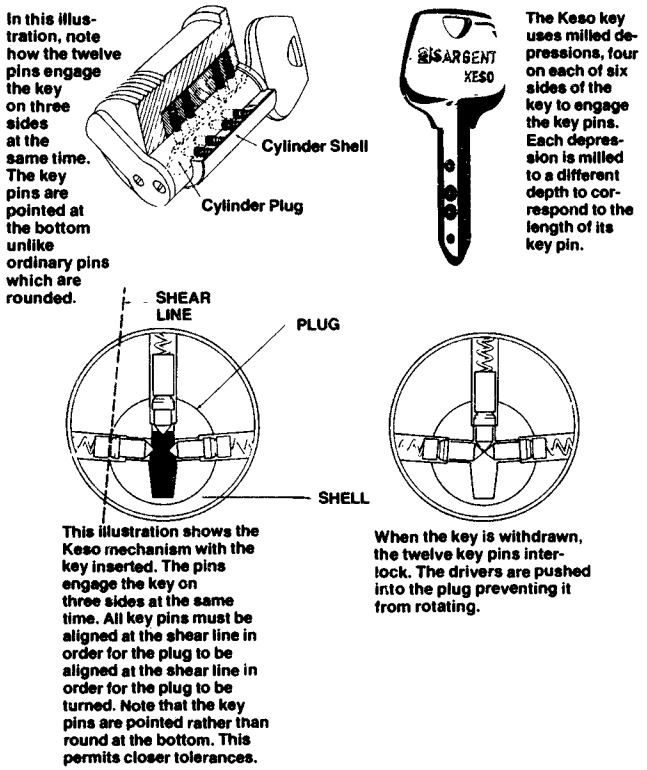

In this illustration, note how the twelve pins engage the key on three sides at the same time. The key pins are pointed at the bottom unlike ordinary pins which are rounded.
Cylinder Shell
Cylinder Plug
SARGENT
KESO
The Keso key uses milled depressions, four on each of six sides of the key to engage the key pins. Each depression is milled to a different depth to correspond to the length of its key pin.
SHEAR LINE
PLUG
SHELL
This illustration shows the Keso mechanism with the key inserted. The pins engage the key on three sides at the same time. All key pins must be aligned at the shear line in order for the plug to be aligned at the shear line in order for the plug to be turned. Note that the key pins are pointed rather than round at the bottom. This permits closer tolerances.
When the key is withdrawn, the twelve key pins interlock. The drivers are pushed into the plug preventing it from rotating.

Figure 1-23. The Sargent Keso mechanism.

The Keso lock can be master keyed to seven levels (compared to four levels in the conventional pin tumbler lock). Because of the use of twelve pins and variable pin spacing which provides a very high number of combinations to eliminate cross keying, the Keso lock can be master-keyed with no significant loss of security.

Medeco Sidebar Pin Tumbler Cylinder Mechanism. This cylinder, marketed by the Medeco Lock Company, uses a sidebar in addition to pins to lock the device. When the key is inserted in the lock, the bittings raise special v-shaped key pins to the shear line. In this the Medeco is like any other pin tumbler mechanism. But the key pins also have a groove cut into their sides which is designed to engage a sidebar built into the cylinder plug. The key, therefore, not only must raise the pins to the correct height, but it

must rotate them so that they align with the sidebar. To do this, the key is milled with special slanted bittings which are designed to rotate the v-shaped pins to the correct position. When all of the pins are turned to the right position, the sidebar can retract into the cylinder plug (Figure 1-24).

Two actions are necessary, then, to operate a Medeco mechanism: the pins must be raised to the shear line, and the sidebar must correctly engage the grooves on the pins and retract into the plug. If either alignment does not occur, the plug cannot be turned. This secondary sidebar element is the basis of the high security of the Medeco cylinder. (One model of the Medeco used on cam locks depends totally on the sidebar mechanism for security as it has no upper pins or drivers.)

The Medeco uses five pins each with a number of different angles of rotation which, taken together, provide several million useful combinations. The lock is constructed with hardened materials inserted to prevent drilling and uses close tolerances. The special features of the Medeco make it almost impossible to pick. Not only must the pins be raised to the correct height, they must also be rotated to the correct position. This rotation is extremely difficult to achieve without the proper key.

The Abloy Principle. The main functioning part of the Abloy cylinder consists of 7 to 13 rotating detainer discs (Figure 1-25). They feature mechanical pick-resistance—the edges of the discs, where the cut is located, cannot be reached by picking tools. The detainer discs are independent of springs, which increases durability. There are over 360 million combinations possible. All the Abloy padlocks can be keyed alike as long as they are of the same keyway.

The Abloy rotating detainer disc features false gates for pick resistance. The tailpiece keeps the discs aligned properly in the cylinder. The detainer discs are of stamped brass.

There are six combination cut locations. The numbers range from 0 to 5, and are read from left to right as you go around the top of the disc. The first step to remember in disc identification is to imagine the disc as the face of a clock. With the tailpiece in the 6 o'clock position, and the top center of the disc at the 12 o'clock position, note that the 0, 1 and 2 cuts are to the left of the 12 o'clock position, and the 3, 4 and 5 cuts are to the right

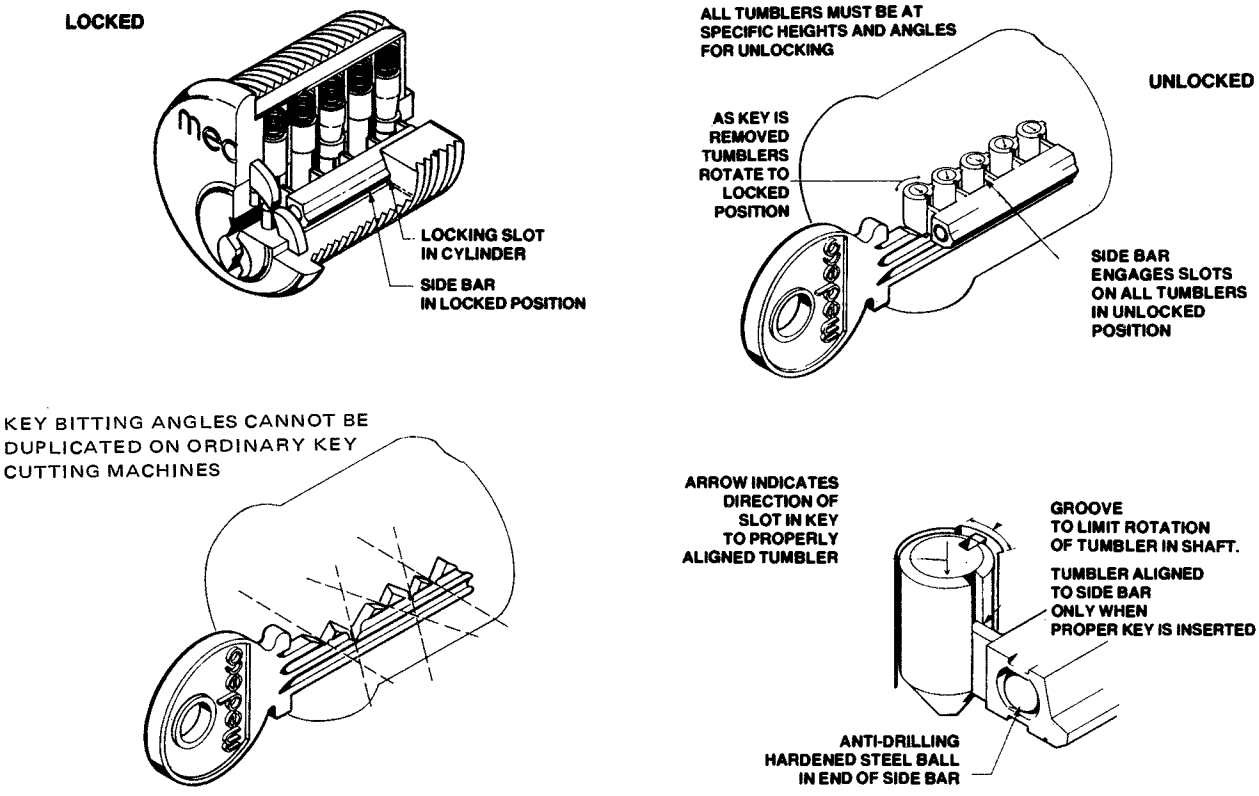

LOCKED
LOCKING SLOT IN CYLINDER
SIDE BAR IN LOCKED POSITION
ALL TUMBLERS MUST BE AT SPECIFIC HEIGHTS AND ANGLES FOR UNLOCKING
UNLOCKED
AS KEY IS REMOVED TUMBLERS ROTATE TO LOCKED POSITION
SIDE BAR ENGAGES SLOTS ON ALL TUMBLERS IN UNLOCKED POSITION
KEY BITTING ANGLES CANNOT BE DUPLICATED ON ORDINARY KEY CUTTING MACHINES
ARROW INDICATES DIRECTION OF SLOT IN KEY TO PROPERLY ALIGNED TUMBLER
GROOVE TO LIMIT ROTATION OF TUMBLER IN SHAFT.
TUMBLER ALIGNED TO SIDE BAR ONLY WHEN PROPER KEY IS INSERTED
ANTI-DRILLING HARDENED STEEL BALL IN END OF SIDE BAR

Figure 1-24. Medeco high security sidebar mechanism.

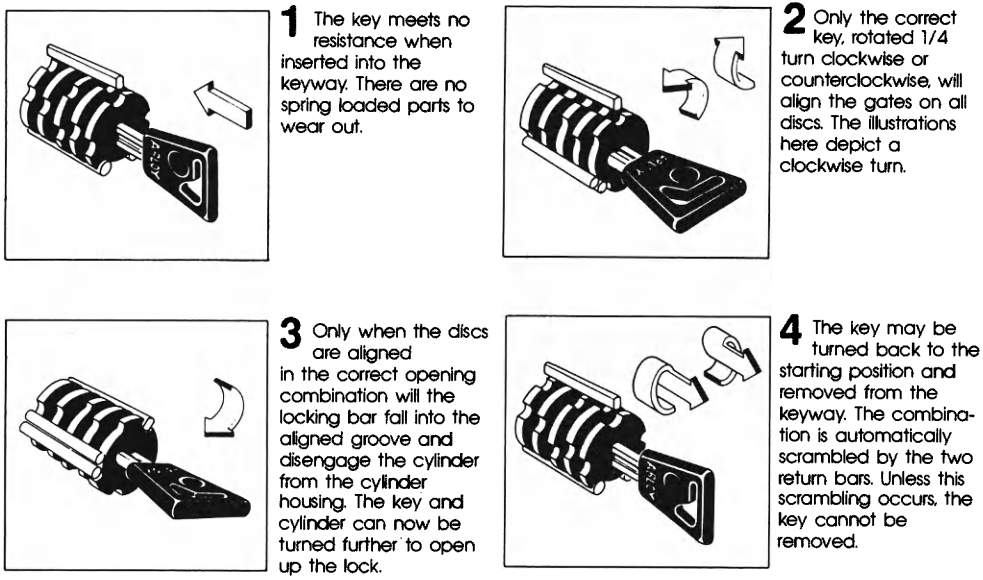

1 The key meets no resistance when inserted into the keyway. There are no spring loaded parts to wear out.
2 Only the correct key, rotated 1/4 turn clockwise or counterclockwise, will align the gates on all discs. The illustrations here depict a clockwise turn.
3 Only when the discs are aligned in the correct opening combination will the locking bar fall into the aligned groove and disengage the cylinder from the cylinder housing. The key and cylinder can now be turned further to open up the lock.
4 The key may be turned back to the starting position and removed from the keyway. The combination is automatically scrambled by the two return bars. Unless this scrambling occurs, the key cannot be removed.

Figure 1-25. Abloy rotating disc. (1) Key meets no resistance when inserted into keyway. There are no spring-loaded parts to wear out. (2) The correct key, turned 90°, will rotate the detainer discs to the correct combination. (3) When the discs are in the correct combination, the locking bar enters the slot and allows the key to be turned further to open the lock. (4) To withdraw the key, turn in reverse direction until it stops. This automatically scrambles the detainer disc combination. Key meets no resistance when exiting keyway.

of it. When the discs are laying on a table in front of you, you can readily determine if the disc is in the 0-1-2 range or if it is in the 3-4-5 range. There are only three actual combination discs in the 11.6mm size. They are 0/5, 1/4, and 2/3. By turning over the 0 it becomes a 5. Turning over the 1 disc it becomes a 4 and the 2 becomes a 3. The next step for disc identification is to imagine the discs being stamped out of a sheet of brass. The top edges are left rounded and the bottom edges are sharp. (0,2,4 are smooth.) There is an exception to this rule. It does not apply to non-false gate discs which are placed randomly within a cylinder to confuse attempts to pick the lock. These discs are produced in limited amounts.

In looking at the 13.5mm disc, notice that with the tail piece in the 6 o'clock position, the keyway is in a different position than with the 11.6mm discs. With the keyway in a different position it is obvious that the other difference is that the discs cannot be flipped over to obtain another cut number as with the 11.6mm disc. Therefore, each cut number of the 13.5 disc is on its own disc. With the tailpiece at the 6 o'clock position, the cut numbers are in the same location as in the 11.6mm.

The lifting zero, which is made of hardened steel, has an angle on one side of the cut. This angle is used to lift the locking bar out of the cylinder. The lifting zero is used as both the top and bottom disc to lift the sidebar evenly. The top lifting zero has no tailpiece, and is referred to as the rotating lifting zero. It can be rotated with the top of the key to be used as a dust cover, and also provides some protection by spinning when drilling is attempted.

The first disc assembled in the tip of the cylinder is the lifting zero. The last disc assembled in the cylinder is the rotating lifting zero. In between are the combination discs. Also, between each disc is a spacer. The spacer is used like a bearing to reduce friction and wearing of the discs. Also, minimal contact between the spacer and the disc helps protect the lock from freezing. The spacer is made of a tin-copper material with a hole in the center to allow passage of the key, and a notch at the top which aligns with the sidebar groove in the cylinder to allow the sidebar to drop into the aligned cuts of the disc. The bottom of the spacer is flanged so it can align with the edges of the cylinder opening to ensure correct positioning of the cylinder. The spacer

is convex on one side and concave on the other. Either side can be facing up when it is put in the cylinder.

ASSA Twin 6000 High Security Cylinder. The ASSA Twin 6000 cylinder utilizes two independent locking mechanisms which are simultaneously operated by a specially shaped key (Figure 1-26). The primary system is of conventional pin tumbler design, and the secondary is a sidebar system. The key has a corresponding sidebar code which is factory cut, and a system code which can be cut on most duplicating and code machines. When the proper key is inserted, the 6-pin conventional pin tumbler system creates a shear line. In addition, five special sidebar pins are positioned to individual heights which correspond to the sidebar code. The sidebar code on the key matches the code on the sidebar and allows the sidebar to "cam out" in the plug as the key is turned. Only when both systems are correct will the key operate the cylinder.

The independent systems of this ASSA cylinder, eleven pins total, makes picking impractical. Additionally, inactive "dummy" grooves in the side pins catch the sidebar when improperly positioned and when rotational force is applied, the "mushroom" drivers are caught by the counter millings in the cylinder plug.

This ASSA cylinder is also drill resistant. The pins are stainless steel, hardened stainless or nickel silver. In addition to side and system pins, case hardened, drill resistant inserts are embedded in the cylinder plug and housing.

Emhart Interlocking Pin Tumbler Mechanism. The critical feature of the unit is the use of interlocking pin tumblers in the cylinder. Like the Medeco mechanism, these must not only be raised to their proper heights, but rotated so that the interlocks face the direction of plug rotation before the lock can be operated. These functions—raising the pins and rotating them—are accomplished by a special key that has bittings cut on an angle like the Medeco key which engage v-shaped key pins. The mechanism is almost impossible to manipulate. The use of six pins with many different angles of rotation for each pin provides millions of different useful combinations. Master keying reportedly does not appreciably decrease the security of this system as special interlocking master pins are used. This lock is marketed under Corbin, Russwin and Safe trademarks (Figure 1-27).

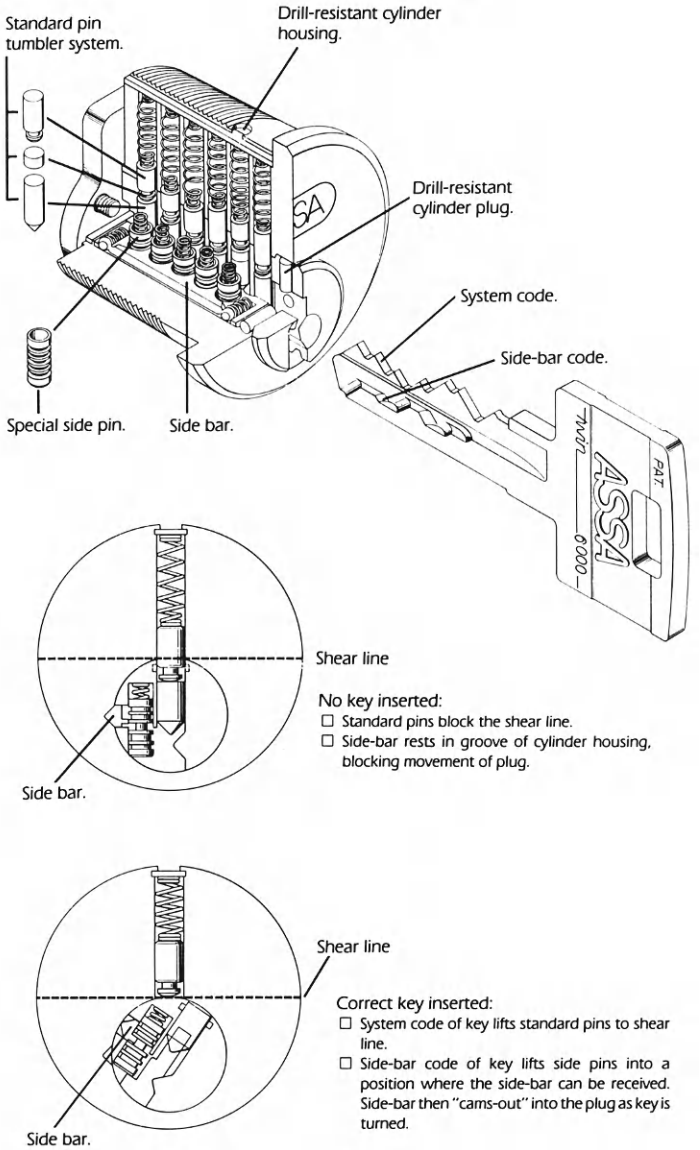

Standard pin tumbler system.
Drill-resistant cylinder housing.
Drill-resistant cylinder plug.
System code.
Side-bar code.
Special side pin.
Side bar.
ASSA
PAT.
Shear line
No key inserted:
☐ Standard pins block the shear line.
☐ Side-bar rests in groove of cylinder housing, blocking movement of plug.
Side bar.
Shear line
Correct key inserted:
☐ System code of key lifts standard pins to shear line.
☐ Side-bar code of key lifts side pins into a position where the side-bar can be received. Side-bar then "cams-out" into the plug as key is turned.
Side bar.

Figure 1-26. ASSA Twin 6000 High-Security Cylinder.

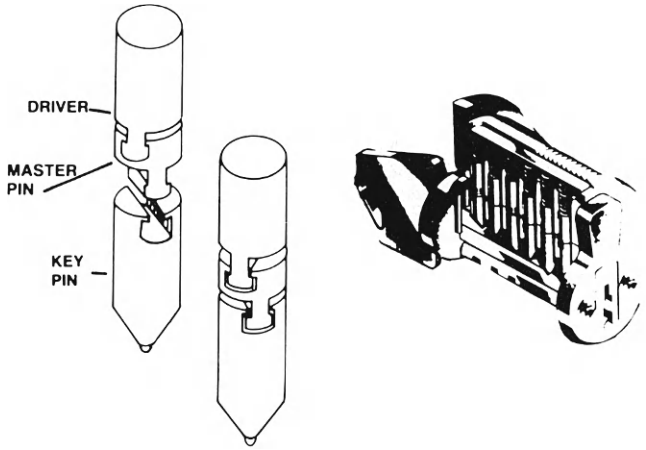


Figure 1-27. Emhart interlocking pin tumbler mechanism. In this drawing, all of the pins have been rotated by the angular cut key so that the interlocks face the direction of plug rotation. The mechanism is now ready to be rotated. Note that the angles of rotation would be different depending upon whether the shear line would be at the top of the key pin or the top of the master pin.

Lever Tumbler Mechanisms

Although the lever lock operates on the same principles as the pin or disc tumbler mechanism, its appearance is very different. Figure 1-28 illustrates a typical lever mechanism. Unlike pin or disc tumbler devices, the lever lock does not use a rotating core or plug, and the bolt is usually an integral part of the basic mechanism thrown directly by the key. The only other type of mechanism in which the key directly engages the bolt is the warded mechanism. You will recall that the bolt in pin or disc tumbler systems is usually directly operated by the *cylinder plug*, not the key. The key is used to rotate the plug, but never comes into direct contact with the bolt.

Despite these somewhat deceptive appearances, the lever lock operates very much like the other tumbler mechanisms. Each *lever* is hinged on one side by the *post* which is a fixed part of the *case*. The leaf *springs* attached to the levers hold them down in a position which overlaps the *bolt notch* as shown in Figure 1-29a.

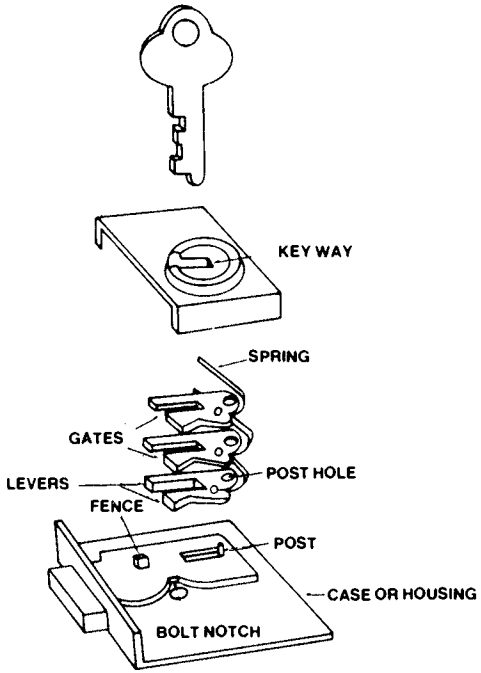


Figure 1-28. Lever tumbler mechanism.

In this position, the *bolt* is prevented from moving back into a retracted position by its *fence* which is trapped by the front edges (*shoulders*) of the levers. When the key is inserted and slightly rotated, the bittings on the key engage the *saddle* of the lever raising it to a position where the fence aligns with the slot in the lever (called the *gate*). In this position, the fence no longer obstructs the movement of the bolt to the rear, and the bolt can be retracted (Figure 1-29b).

The retraction is accomplished by the key engaging the shoulder of the bolt notch. While the bittings of the key are still holding the levers in an aligned position, the key contacts the rear shoulder of the bolt notch, forcing the bolt to retract as the key is rotated (Figure 1-29c). As the bolt is retracted, the fence moves along the gate until the bolt is fully withdrawn. When the key has rotated fully, completely retracting the bolt, it can be withdrawn (Figure 1-29d).

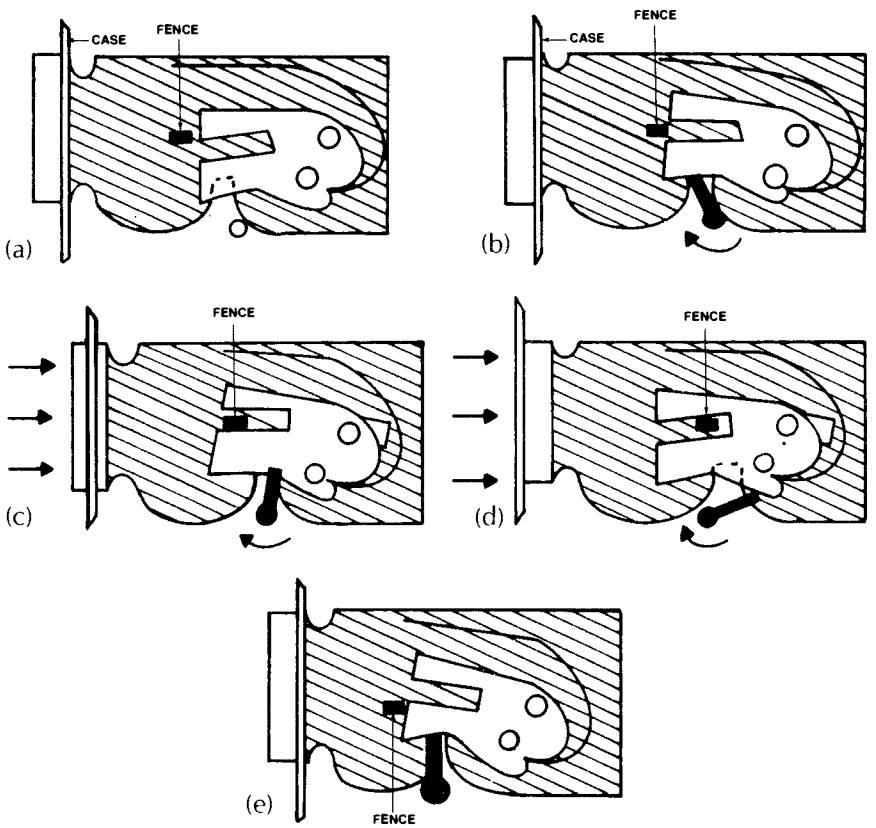


Figure 1-29. Operation of a typical lever tumbler mechanism. a. The bolt is in the fully extended "locked" position and the key has been withdrawn from the keyway. In this position, the spring forces the lever down toward the bolt notch, trapping the fence against the forward edge (shoulder) of the lever. This prevents the bolt from being forced back. b. The key has been inserted and the bitting on the key has lifted the lever against the spring tension, aligning the gate with the fence. The bolt can now be moved back into the retracted position. c. The key has begun to force the bolt back into a retracted position by engaging a shoulder of the bolt notch at the same time it is keeping the lever suspended at the correct height to allow the fence to pass into the gate. d. The bolt is now fully retracted and the key can be withdrawn. e. If an improper key is inserted, the bitting either will not lift the lever high enough for the fence to pass through the gate or the lever will be raised too high and the fence will be trapped in front of the lower forward shoulder of the lever. From this position, the bolt cannot be forced back into the retracted position.

If an improperly cut key is inserted and rotated in the lock, either the levers will not be raised far enough to align all of the gates with the fence, or one or more levers will be raised too high, so that the bottom edge of the lever obstructs the fence (as in Figure 1-29e). In either case, the bolt is prevented from being forced to the rear, thus opening the lock.

Figure 1-30a shows one version of the basic lever. A number of variations are on the market. Some levers are made with projections built into the gate designed to trap the fence in various positions (Figure 1-30b). The front and rear traps prevent the fence from being forced through the gate when the bolt is in either the fully extended or fully retracted position. Figure 1-30c shows another variation: serrated (saw-tooth) front edges. These serrations are designed to bind against the fence when an attempt is made to *pick* the lock. They are commonly found on high-security lever tumbler mechanisms.

Lever mechanisms provide moderate to high security depending on the number of levers used, their configuration, and the degree

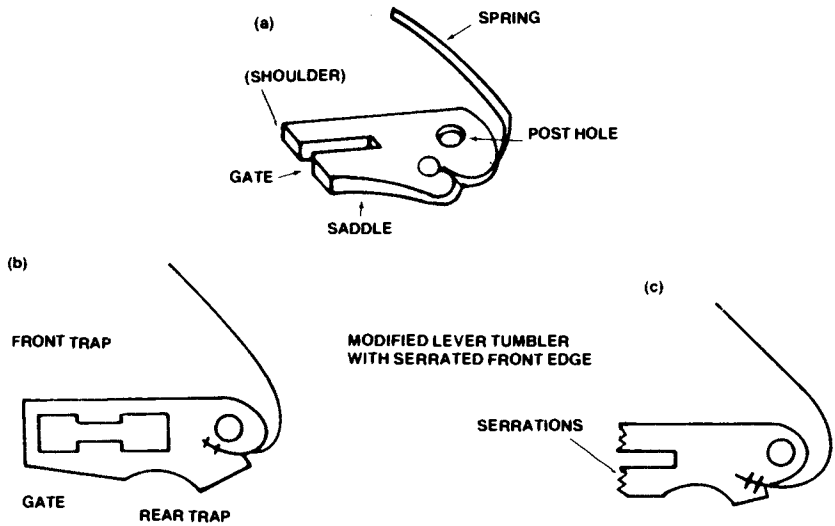


Figure 1-30. Lever tumblers. To operate the lock, the key contacts the lever at the saddle, lifting it until the fence is aligned with the gate. The saddles on the various tumblers are milled to different depths to correspond to different cuts on the key.

of care used in the construction of the lock mechanism. Any mechanisms using six or more tumblers can safely be considered a high-security lock. Some mechanisms use a double set of levers, requiring a double bitted key. The levers are located on both sides of the keyway. This configuration makes the lock very difficult to pick or manipulate.

Lever locks are commonly found in applications where moderate to high security is a requirement, including: safe deposit boxes, strong boxes, post office boxes, and lockers. The lever mechanisms available in the United States, because of the integrated short throw bolt are not ordinarily used as builders hardware. But they are commonly used in that application in Europe and some of these locks have found their way into the United States.

COMBINATION LOCKS

In principle, a combination lock works much the same way as a lever mechanism. When the tumblers are aligned, the slots in the tumblers permit a fence to retract which releases the bolt so that the bolt can be opened. The difference is that where the lever mechanism uses a key to align the tumblers, the combination mechanism uses numbers, letters or other symbols as reference points which enable an operator to align them manually. Figure 1-31 shows a simplified view of a typical three-tumbler combination lock mechanism. The tumblers are usually called *wheels*. Each wheel has a slot milled into its edge which is designed to engage the *fence* when the slot has been properly aligned. This slot is called a *gate*. The fence is part of the lever which retracts the bolt. The gates are aligned with the fence by referring to letters, numbers, or other symbols on the dial. The sequence of symbols which permits the lock to operate are its *combination*. A typical combination sequence using numbers is 10-35-75. The fact that three numbers are used in the combination indicates that the lock contains three tumblers. The number of tumblers in a lock always corresponds to the number of symbols used in its combination. Few modern combination locks use more than four tumblers because combinations of five or more symbols are unwieldy and hard to remember. Older models, however, used as many as six.

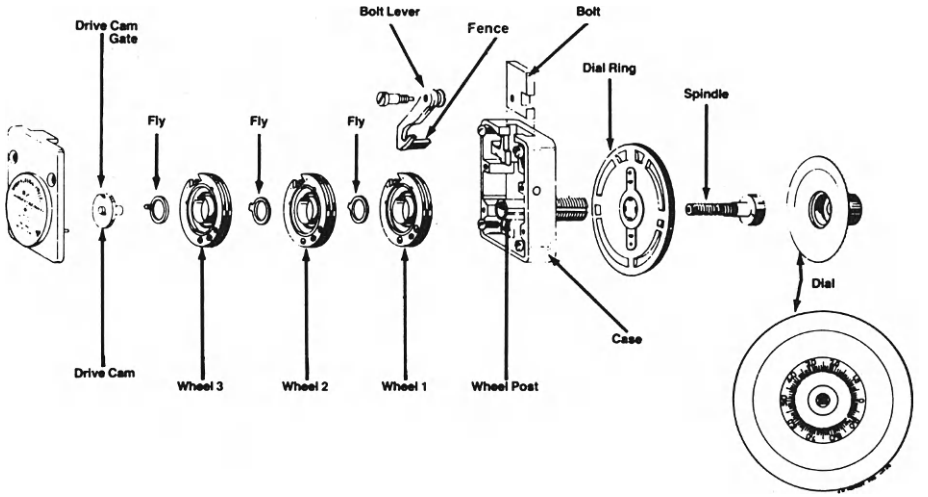


Figure 1-31. Three-tumbler combination.

Both *drive cam* and dial are fixed to the *spindle* so that as the dial is rotated, the drive cam will also rotate in an identical fashion. The drive cam has two functions. It is the means by which motion of the dial is transferred to the wheels, and when all wheels are properly aligned and the fence retracted, it is the mechanism by which the bolt lever is pulled to retract the bolt.

The wheels are not fixed to the spindle, but ride on a *wheel post* which fits over the spindle (Figure 1-31). These wheels are free-floating and will not rotate when the dial is turned unless the *flies* are engaged. The flies are designed to engage pins on the wheels at predetermined points (determined by the combination of that particular lock). When the flies engage these pins, the wheels pick up the rotating motion of the dial. When the flies are not engaged, the wheels will remain in place when the dial is rotated.

To operate a typical three-wheel combination lock, the dial is first turned four times in one direction to allow all of the flies to engage their respective wheels so that as the dial is being turned, all of the wheels are rotating with it. At this point the wheels are said to be *nested.* The object at this point is to disengage each wheel at the spot where its gate will be aligned with the fence. To do this, the operator stops the dial when the first number of

the combination reaches the index mark on the dial ring. This first stop aligns the gate of wheel 1 with the fence.

The operator then reverses direction to disengage wheel 1, which remains stationary, and rotates the dial three turns to the second number in the combination. When this number is under the index mark, wheel 2 is aligned. Again reversing direction to disengage wheel 2, the operator makes two turns to the last number of the combination. This aligns wheel 3. At this point all of the gates are aligned with the fence. The operator then reverses direction once again and turns the dial until it stops.

This last operation has two functions. It aligns the gate on the drive cam with the fence which permits the fence to retract into the space provided by the three gates in the wheels and the fourth gate in the drive cam. The bolt lever is now engaged with the wheels and drive cam. As the operator continues rotating the dial, the drive cam pulls the bolt lever to retract the bolt. When the dial will no longer rotate, the bolt is fully retracted, and the lock is "open."

The security afforded by combination mechanisms varies widely. The critical elements are the number of tumblers used in the lock, the number of positions on the tumbler where the gate can be located, and the tolerances in the width of the gate and fence. Wide tolerances allow the fence to enter the gates even when they are not quite completely aligned. So that, although the proper combination may be 10-35-75, the lock may also operate at 11-37-77.

The number of positions the gate can occupy on each tumbler and the number of tumblers employed in the mechanism determine the number of combinations that can be used. Each dial division corresponds to a possible location of a gate on a tumbler. Therefore, a dial with fifty divisions indicates that only fifty gate positions are possible. A dial with one hundred divisions indicates a possible one hundred positions, and so on. The number of combinations that can possibly be used with a particular lock are determined by taking the number of dial divisions raised to the power of the number of tumblers. A lock with fifty positions and three tumblers would, therefore, have 50^3 or 125,000 potential combinations. One hundred positions and three tumblers would yield one million possible combinations. And the same lock using six tumblers would provide one trillion (1,000,000,000,000)

possible combinations. The number of combinations that can actually be used (useful combinations) is limited by a number of mechanical and manufacturing limitations, but not to the extent of the limitations imposed on key-operated mechanisms. Consequently, after all of the unusable combinations are subtracted, the number of useful combinations remains quite large.

Until the 1940s it was often possible to open many combination locks by using the sound of the movement of the tumblers and feeling the friction of the fence moving over the tumblers as indicators of tumbler position. (Tumblers in combination locks do not "click" despite Hollywood's contentions to the contrary.) Skilled operators were often able to use sound and feel to determine when each tumbler came into alignment. Modern technology has all but eliminated these possibilities, however, through the introduction of sound baffling devices, nylon tumblers, improved lubricants to eliminate friction, false fences and cams which suspend the fence over the tumblers so that they do not make contact until after the gates are already aligned (see Figure 1-31).

Another manipulation technique of recent vintage utilized the fact that the tumbler wheels with gates cut into them are unbalanced—more weight is on the uncut side than on the cut side. By oscillating the dial, these cut and uncut sides could be determined, and the location of the gates estimated. The introduction of counter-balanced tumblers has virtually eliminated this approach to the better mechanisms.

Radiology has also been used to defeat combination locks. A piece of radioactive material placed near the lock can produce "ghost" images of the tumblers on sensitive plates showing the location of the gates. Nylon and teflon tumblers and shielding material which are opaque to radiation are used to defeat this technique.

It is probably fair to say that modern, high-security manipulation-resistant combination locks are almost impossible to defeat by any currently known method. This does not, however, ignore the fact that new techniques are being tried all the time, and the laws of probability make it almost a certainty that someone will eventually find a method of surreptitiously entering even the best mechanisms. Meanwhile, there are thousands of less secure standard mechanisms which are

still vulnerable to the methods described above. While these will undoubtedly frustrate most illicit operators, they are not proof against the very skilled, and if a very high degree of security is required in a particular application, modern, high-security locks should be used.

2

Lock Bodies

Most lever tumbler and warded mechanisms contain an integrated bolt as a part of the mechanism. The key operates directly to throw the bolt, thereby opening and locking the lock. This is not true of pin and disc tumbler locks. These consist of two major components. The cylinder plug, the shell, the tumblers and springs are contained in an assembly known as the *cylinder*. The other major component is the *lock body* which consists of the *bolt assembly* and case or housing. The bolt assembly consists of the bolt itself, a *rollback*, and a *retractor*. This assembly translates the rotating motion of the cylinder plug to the back-and-forth motion that actually operates the bolt. When the cylinder is inserted into the lock body, it is typically connected to the bolt assembly by a *tail piece* or *cam*. A cylinder can be used in a number of different lock bodies. Here we will be primarily concerned with the types of bodies used on standard residential and light commercial doors. The pin tumbler is the usual mechanism used in these locks, although some manufacturers offer door locks using disc tumbler cylinders (such as the Schlage Cylindrical Lock introduced earlier).

BOLTS

There are two types of bolts used for most door applications. The *latch bolt* and the *deadbolt*. Examples of these are illustrated in Figure 2-1. They are easily distinguished from each other. A latch bolt always has a beveled face while the face on a standard deadbolt is square.

Latch Bolt

This bolt, which is sometimes called simply a "latch," a "locking latch" (to distinguish it from non-locking latches), or a "spring bolt" is always spring-loaded. When the door on which it is mounted is in the process of closing, the latch bolt is designed to automatically retract when its beveled face contacts the lip of the strike. Once the door is fully closed, the latch springs back to extend into the hole of the strike, securing the door.

A latch bolt has the single advantage of convenience. A door equipped with a locking latch will automatically lock when it is closed. No additional effort with a key is required. It does not, however, provide very much security.

The throw on a latch bolt is usually three-eighths and seldom more than five-eighths inches. Because it must be able to retract

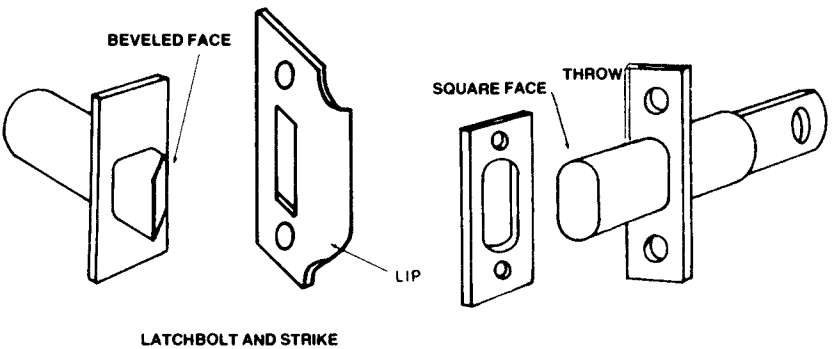


Figure 2-1. Basic types of bolts. The bolt on the right is a horizontal long-throw deadbolt and strike. Throw is measured from the face plate to the end of the bolt with the bolt in fully extended position.

into the door on contact with the lip of the strike, it is difficult to make the throw much longer. But, because there is always some space between the door and the frame, this means that a latch may project into the strike no more than one-quarter inch (often as little as one-eighth inch on poorly hung doors). Most door jambs can be spread at least one-half inch with little effort, permitting an intruder to quickly circumvent the lock.

Another undesirable feature of the latch bolt is that it can easily be forced back by any thin shim (such as a plastic credit card, or thin knife) inserted between the face plate of the lock and the strike. Anti-shim devices have been added to the basic latch bolt to defeat this type of attack. They are designed to prevent the latch bolt from being depressed once the door is closed. Figure 2-2a shows a latch bolt with anti-shim device. These are often called *deadlocking latches*, a term which is mildly deceptive since these latches do not actually deadlock and they are not nearly as resistant to jimmying as deadlocks. Often a thin screwdriver blade can be inserted between the face plate and the strike, and pressure applied to break the anti-shim mechanism and force the latch to retract.

Another type of latch bolt is shown in Figure 2-2b. This is an *anti-friction latch bolt*. The anti-friction device is designed to

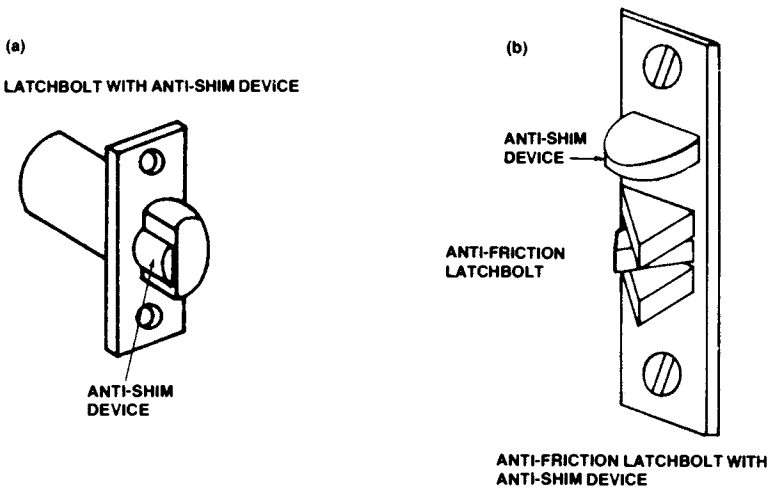


Figure 2-2. Modified latchbolts.

reduce the closing pressure required to force the latch bolt to retract. This permits a heavier spring to be used in the mechanism. Most modern anti-friction latches also incorporate an anti-shim device. Without it, the anti-friction latch is extremely simple to shim.

Deadbolt

The deadbolt is a square-faced solid bolt which is not spring-loaded and must be turned by hand into either the locked or unlocked position. When a deadbolt is incorporated into a locking mechanism, the result is usually known as *deadlock*. The throw on a standard deadbolt is also about one-half inch, which provides only minimal protection against jamb spreading. A *long-throw deadbolt*, however, has a throw of one inch or longer. One inch is considered the minimum for adequate protection. Properly installed in a good door using a secure strike, this bolt provides reasonably good protection against efforts to spread or peel the jamb.

The ordinary deadbolt is thrown horizontally. On some narrow-stile doors, such as aluminum-framed glass doors, the space provided for the lock is too narrow to permit a long horizontal throw. The *pivoting deadbolt* is used in this situation to get the needed longer throw (Figure 2-3a). The pivoting movement of the bolt allows it to project deeply into the frame—at least one inch, usually more. A minimum of one inch is recommended. When used with a reinforced strike, this bolt can provide good protection against efforts to spread or peel the frame.

Increased security against jamb spreading is provided by a number of different types of deadbolts which collectively are known as *interlocking deadbolts*. These are specifically designed to interlock the door and the strike so that the door jamb cannot be spread. The most common of these is the *vertical-throw deadbolt* shown in Figure 2-3b. This is usually a rim-mounted device. The other two devices shown in Figure 2-3b [the *expanding bolt deadbolt* (Figure 2-3c) and the *rotating deadbolt* (Figure 2-3d)] are meant to be mounted inside the door. These locks require a securely mounted strike or they are rendered ineffective.

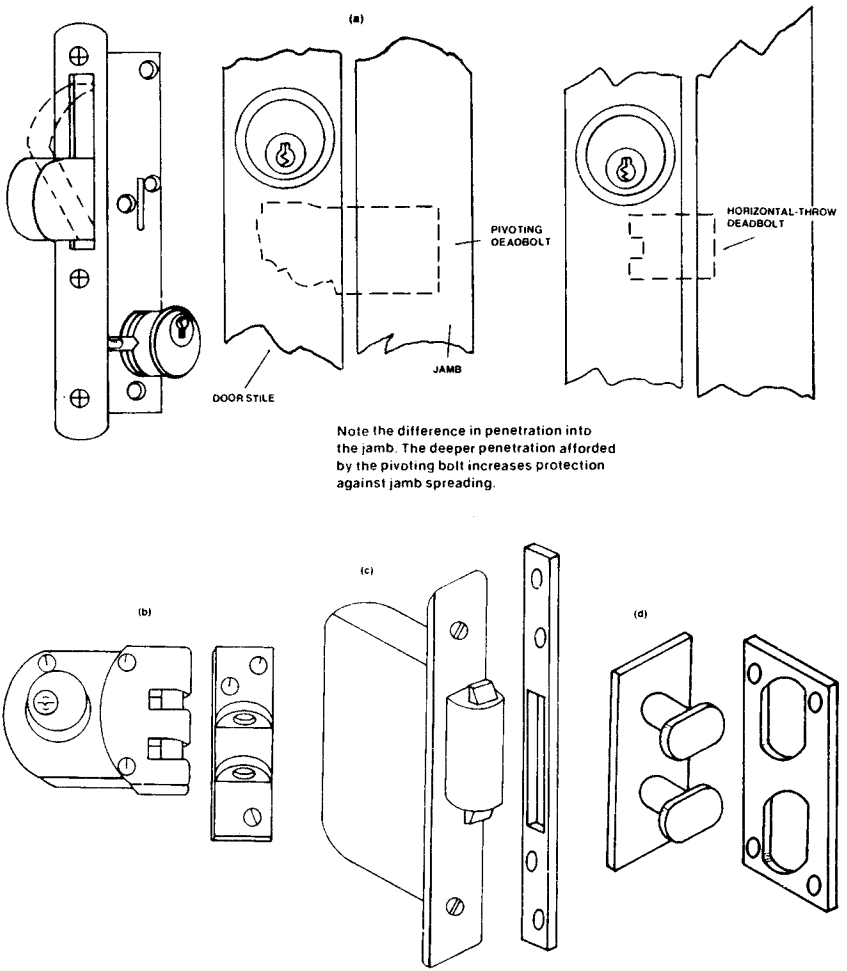


Figure 2-3. Modified deadbolts. a. Pivoting deadbolt. b. Vertical-throw deadbolt. c. Expanding deadbolt. d. Rotating deadbolt.

DOOR LOCK TYPES

Five basic lock types are used on most doors in the United States: rim-mounted, mortise, tubular, unit and cylindrical. Each of these has a number of advantages and disadvantages from the

point of view of the protection offered. Each, however, with the single exception of the cylindrical lockset, can offer sound security when a good lock is properly installed.

Mortise

It was but a few years ago that almost all residential and light commercial locks were mortise locks. A mortise lock, or lockset, is installed by hollowing out a portion of the door along the front or leading edge and inserting the mechanism into this cavity. Suitable holes are then drilled into the side of the door in the appropriate spot for the cylinders and door knob spindle (where the door knob is part of the unit, as is usually the case). Figure 2-4a shows a typical mortise lockset. These mechanisms require a door which is thick enough to be hollowed out without losing a great deal of its strength in the process. One of the major weaknesses of mortise locks is that the cylinder is usually held in the lock with a set screw which provides very little defense against pulling or twisting the cylinder out of the lock with a suitable tool. Cylinder guard plates can be used to strengthen this lock's resistance to this threat. On some mortise locks, the trim plate acts as a cylinder guard.

Rim-Mounted

A rim-mounted mechanism is very simply any lock which is installed on the surface (rim) of the door (Figure 2-4b). Most are used on the inside surface, since outside installation requires a case that is reinforced against direct attacks on the case itself. Commonly these are supplementary locks installed where the primary lock is not considered enough protection. These may or may not be designed for key operation from the outside. If they are, a cylinder extends through the door to the outside where it can be reached by a key.

Tubular

This lock (sometimes called a bore-in) is installed by drilling a hole through the door to accommodate the cylinder (or cylinders) and a hole drilled from the front edge of the door to the cylinder for the bolt assembly (Figure 2-4c). This type of installation has

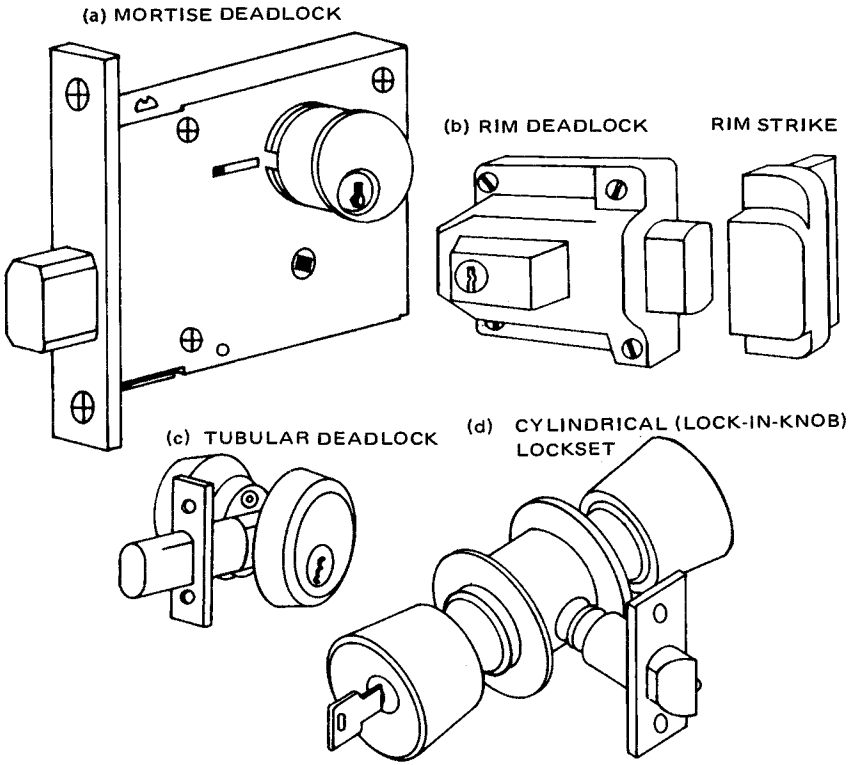


Figure 2-4. Lock types.

virtually replaced the mortise lock in most residential and light commercial applications because it can be installed quickly and by persons of limited skill.

Cylindrical Lockset

The cylindrical lockset ordinarily uses a locking latch as its sole fastening element (Figure 2-4d). It is installed like the tubular lock by drilling two holes in the door. The cylinders are mounted in the door knobs, rather than in a case or inside the door, which makes them vulnerable to just about any attack (hammering, wrenching, etc.) which can knock or twist the knob off the door. Unfortunately, because it is inexpensive and simple to install, about 85% of all residential locks currently being used in new

construction in the United States are of this type. It provides virtually no security whatsoever. There is perhaps no harder or faster rule in lock security than the rule that all cylindrical locks should be supplemented by a secure, long-throw deadbolt. Or, better yet, they should be replaced. A number of more secure locks designed to replace the cylindrical lock are now on the market. These are illustrated in Figure 2-5.

Unit Locks

A unit lock (Figure 2-6) is installed by making a U-shaped cutout in the front edge of the door and slipping the lock into this cutout. This type of lock usually has the advantage of having no exposed screws or bolts. It is ordinarily used in place of mortise locks where the door is too narrow to mortise without considerable loss of strength. A good unit lock (like the Ultra 700) properly installed on a solid door provides excellent protection against attempts to remove the cylinder, or to pry or twist the lock off the doors.

CYLINDERS

Cylinders are mounted in the lock body in a number of ways. Most mortise cylinders are threaded into the lock and secured with a small set screw (Figure 2-7a). Tubular and rim locks use cylinder interlock screws inserted from the back of the lock. Better mechanisms use 1/4 inch or larger diameter hardened steel screws for maximum resistance to pulling and wrenching attacks (Figure 2-7b). Better cylinders incorporate hardened inserts to resist drilling.

Two basic cylinder configurations are available. *Single cylinder* locks use a key-operated cylinder on the outside, and a thumbturn or blank plate on the inside (Figure 2-8a). *Double cylinder* locks use a key-operated cylinder on both sides of the door (Figure 2-8b). This prevents an intruder from breaking a window near the door, or punching a hole through the door, reaching in and turning the lock from the inside. The disadvantage of double cylinders is that rapid exit is made difficult since the key must first be located to operate the inside cylinder. If a fire or other emergency makes rapid evacuation necessary, a double cylinder lock could pose a considerable hazard.

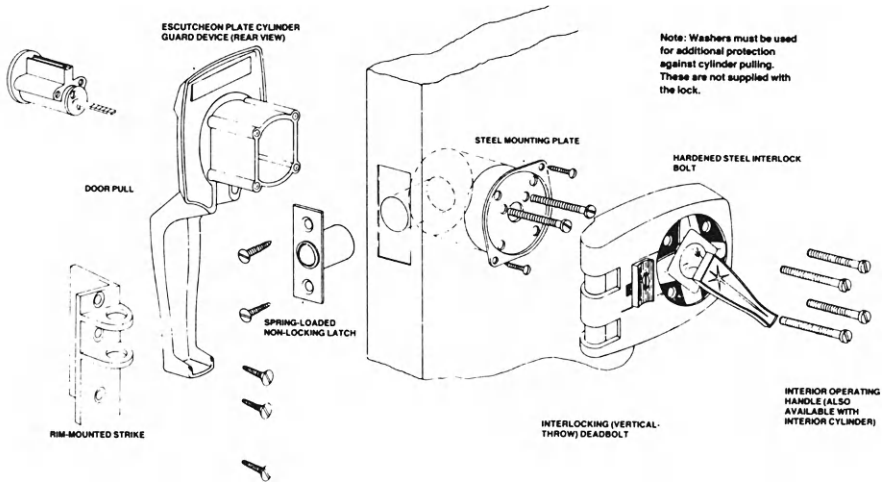

ESCUTCHEON PLATE CYLINDER GUARD DEVICE (REAR VIEW)
Note: Washers must be used for additional protection against cylinder pulling. These are not supplied with the lock.
STEEL MOUNTING PLATE
HARDENED STEEL INTERLOCK BOLT
DOOR PULL
SPRING-LOADED NON-LOCKING LATCH
INTERIOR OPERATING HANDLE (ALSO AVAILABLE WITH INTERIOR CYLINDER)
RIM-MOUNTED STRIKE
INTERLOCKING (VERTICAL-THROW) DEADBOLT

Figure 2-5. Lock types. Ideal Superguard Lock II. This lock is one of a family of recently available locks which incorporate design features intended to frustrate typical burglar attacks. The built-in cylinder guard helps to prevent hammering and prying attacks on the cylinder. The interlocking deadbolt, installed with bolts through the door, frustrates jimmying and punching. The lock is designed to completely replace the cylindrical lockset without additional cutting or drilling on the door. It can be set to lock automatically when the door is closed and is a convenience feature which makes it attractive to many homeowners. It can also be set so that even if the proper key is inserted from the outside, the lock will not operate. This feature provides additional nighttime protection against unwanted intrusion. The lock is available in single and double cylinder versions. The weak points of this particular model are its strike and cylinder mounting. The strike uses long screws (a desirable feature) but these are in-line and too close together. The strike should be made larger to spread any impact over a larger portion of the door jamb and incorporate offset screws to reduce the risk of splitting the jamb. The cylinder is mounted with small-headed machine screws which are inserted through a relatively thin steel mounting plate and engage the back of the cylinder. This thin steel combined with small-headed screws results in a cylinder which is very vulnerable to pulling with a slam hammer or similar tool. The lock would be vastly improved if a more substantial mounting plate and mounting screws with larger heads were provided. Small steel washers used with the mounting screws will provide additional protection—these must be small enough not to interfere with the operation of the cylinder tail piece. The lock is, nevertheless, a vast improvement over the lock-in-knob lockset it is designed to replace and indicates that manufacturers are becoming more aware of the problems inherent in many of the currently used conventional locks.

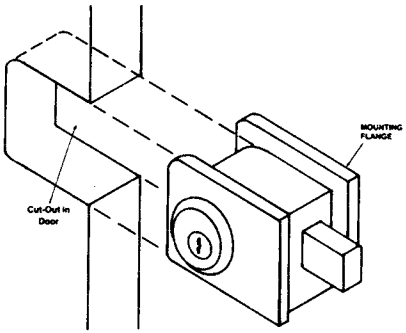


Figure 2-6. Unit lock. The absence of exposed screws and deep mounting flanges increase this particular model's resistance to forceful attacks.

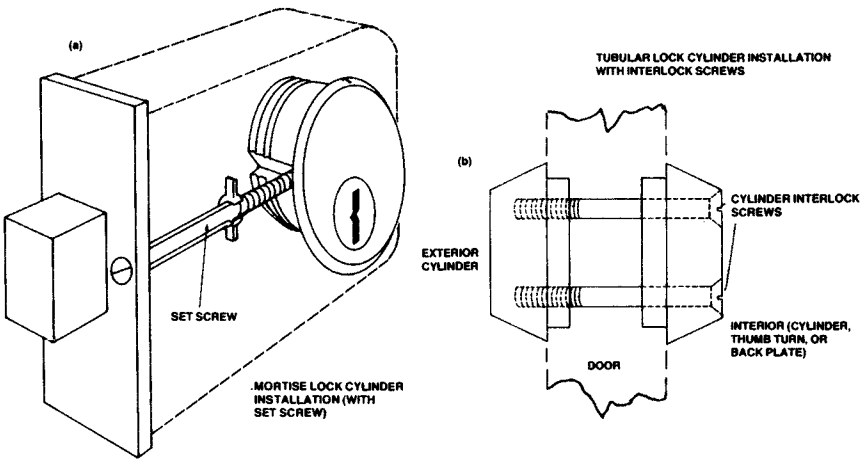


Figure 2-7. (a) Mortise lock and (b) tubular lock cylinder installation.

PADLOCKS

The distinguishing feature of padlocks is that they use a shackle rather than a bolt as the device which fastens two or more objects together (Figure 2-9). The shackle is placed through a hasp which is permanently affixed to the items to be fastened. Three methods

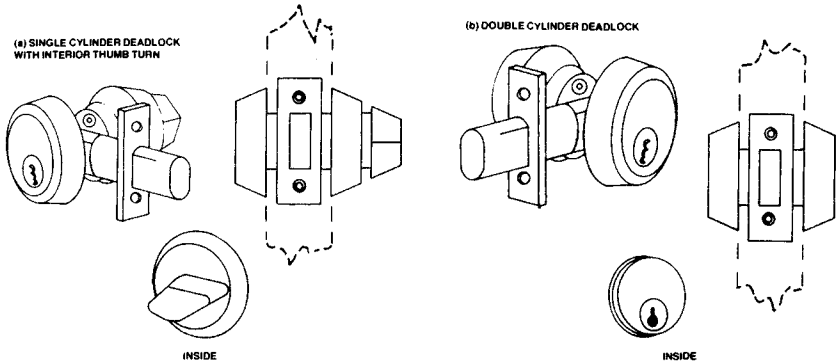


Figure 2-8. Single and double cylinder deadlocks.

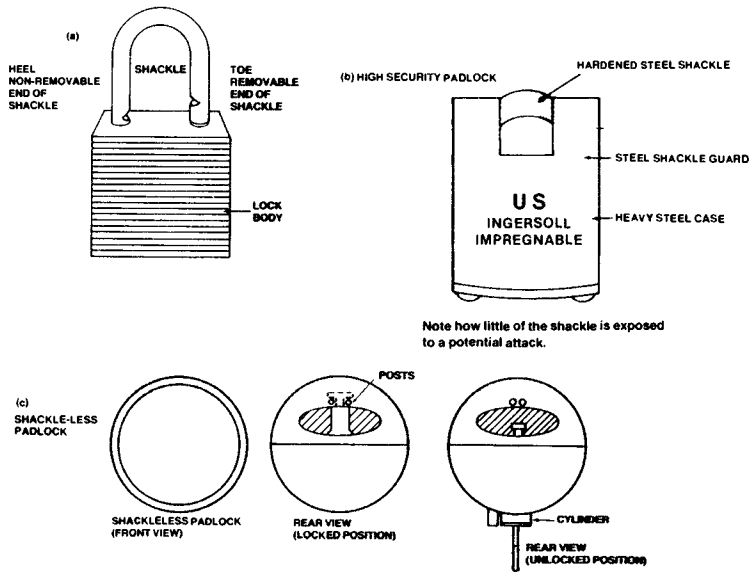


Figure 2-9. Padlocks. a. This is a typical laminated padlock in an unlocked position. The body consists of plates riveted, brazed or soldered together. It provides only limited protection and is subject to a wide variety of attacks. Note the exposed shackle. b. Note how little of the shackle of the high-security padlock is exposed to a potential attack. c. This particular model uses a rotating bolt in place of the traditional shackle as the fastening device. When in the locked position, the bolt is sealed behind two hardened posts.

are commonly used to secure the shackle inside the lock body. The simplest and least secure method is to press a piece of flat spring steel against an indentation in the shackle. When the key is inserted, it rotates to spread the spring releasing the shackle (Figure 2-10a). This is a locking method commonly found on warded padlocks. More rarely it is found on tumbler-type locks, but it is found occasionally on the less expensive models.

A slightly more secure method uses a *locking dog*. The dog is spring-loaded and fits into a notch cut into the shackle (Figure 2-10b). The key is used to retract the dog, permitting the shackle to be withdrawn. Both of these spring-loaded mechanisms are vulnerable to attacks which take advantage of the fact that the locking device can be forced back against the spring by a suitable tool. Shimming and rapping are common techniques used to open them. Often a stiff wire can be pushed down the shackle hole to engage and force back the spring or locking dog. Spring-loaded padlocks should not be used where reasonable security is required.

Positive locking techniques do much to reduce the vulnerability of padlocks to these types of attacks. The most common positive locking method uses steel balls inserted between the cylinder and the shackle (Figure 2-10c). In the locked position, the ball rests half in a groove in the cylinder, and half in a notch cut into the shackle. In this position the shackle cannot be forced past the steel ball. When the cylinder is turned to the unlocked position, the groove deepens, permitting the ball to retract into the cylinder when pressure is put on the shackle. This releases the shackle and opens the lock. These locks are designed so that the key cannot be removed unless the lock is in the locked position.

Padlocks are vulnerable to attacks at several points. The shackle can be pried out of the lock by a crowbar or jimmy, or it can be sawed or cut by bolt cutters. The casing can be crushed or distorted by hammering. Modifications have been incorporated into better padlocks to reduce their vulnerability to these approaches. Heavy, hardened steel cases and shackles are used to defeat cutting and crushing. Rotating inserts and special hardened materials are used to prevent the sawing of shackles. Toe and heel locking is used to prevent prying (Figure 2-10c).

High-security padlocks are large and heavy, using hardened metals in the case, and a thick, hardened, and protected shackle.

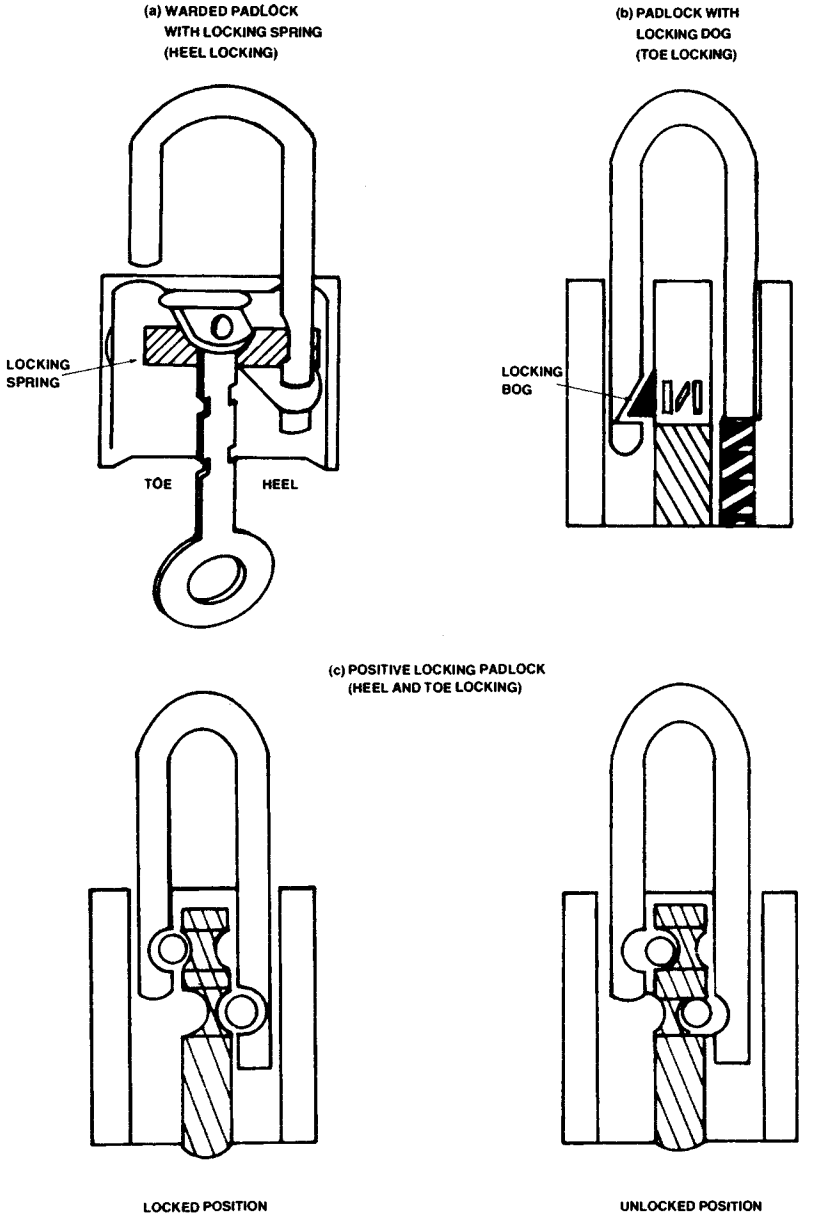


Figure 2-10. Three methods of securing the shackle inside the lock body.

Positive locking methods are always used. As little of the shackle is exposed to attack as possible in the locked position. A typical high-security padlock is shown in Figure 2-9b. A recent variation appears in Figure 2-9c. This is the "shackle-less" padlock which is designed so that a "locking bar" which is contained entirely inside the case is used in the place of an exposed shackle. This is sometimes called a "hasp lock" rather than a padlock.

A padlock is, however, no better than the hasp it engages. Hasps offering reasonable security are themselves made of hardened metals. They must be properly mounted on solid materials so that they cannot be pried off. In the locked position, no mounting screw or bolt should be accessible. Padlocks and hasps should always be considered as a unit. There is no point in mounting a high-security padlock on an inferior hasp. The hasp and lock should always be of approximately the same quality. Where they are not, the complete device is only as good as its weakest member.

STRIKES

Strikes are an often overlooked but essential part of a good lock. A deadbolt must engage a solid, correctly installed strike, or its effectiveness is significantly reduced. The ordinary strike for residential uses is mounted with two or three short (usually less than one inch) wood screws on a soft wood door frame. It can easily be pried off with a screwdriver. High-security strikes are wider, longer, and often incorporate a lip which wraps around the door for added protection against jimmying and shimming (Figure 2-11). Three or more offset wood screws at least 3½ inches long are used to mount the strike. These screws must extend through the jamb and into the studs of the door frame. This provides added protection against prying attacks. Additionally, none of the fastening screws should be in line. In-line screws tend to split soft wood when they are screwed in. Strikes designed for installation on wood frames should always use offset screws as fasteners.

Reinforced steel should be used on metal framed doors, especially aluminum frames. Aluminum is extremely soft metal, and unless a reinforced strike is used, the jamb can be peeled away from the strike area exposing the bolt to a number of

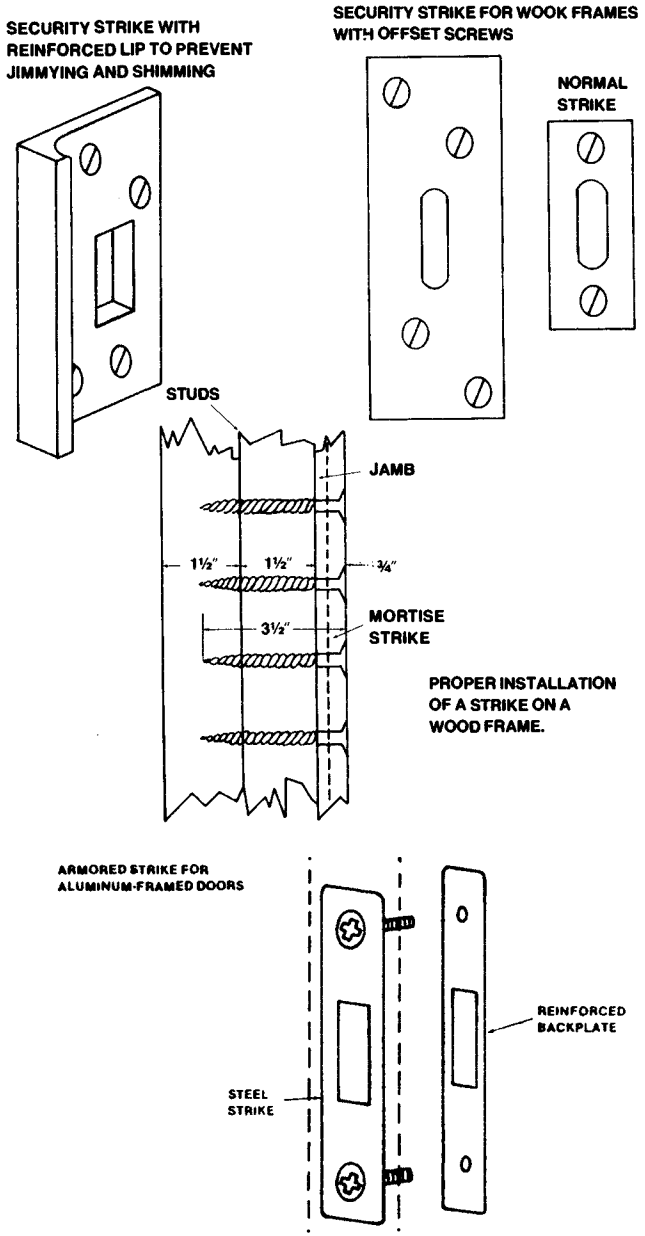
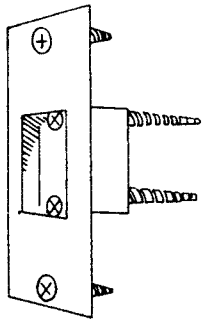
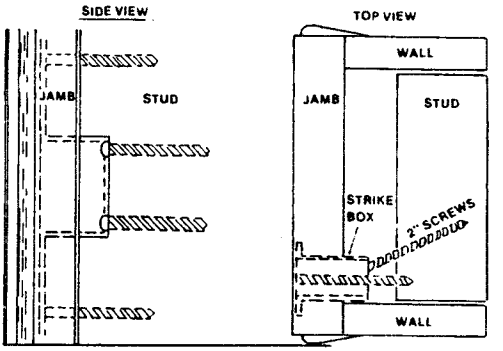


Figure 2-11. High-security strikes.

Figure 2-11 continued.

High-Security Strike Box For Wood Jambs





This strike features two inch hardened screws offset to one side to frustrate most forceful attacks directed at the strike itself

attacks, or allowing it to clear the jamb, thereby freeing the door to open. Bolts should be used to mount strikes in metal frames. If the bolt does not penetrate a substantial steel framing member, then a steel place should be used to lock the bolt (very large steel washers may be an acceptable substitute). This prevents the strike from being pried out of aluminum or thin steel frames.

3

Attacks and Countermeasures

There are two basic methods of attacking locks themselves: surreptitious techniques and force. There are also a number of ways of circumventing a lock by assaulting the objects to which it is fastened which will not be treated here. We will be concerned only with techniques used to defeat locks themselves, and the measures that can be used to forestall those techniques.

No lock is completely invulnerable to attack. A lock's effectiveness is determined by how long it will resist the best effort of an intruder. An expert can pick an average pin tumbler cylinder in seconds, and no lock can survive strong force applied for a sufficient length of time. The sole object of using any lock at all is to *delay* an intruder. A good lock makes entry riskier or more trouble than it's worth, and that is the objective. Fortunately, most potential intruders are not experts, thus most moderately secure locks can survive for a reasonable amount of time against common attack techniques.

The proper use of countermeasures will significantly reduce a locking system's vulnerability to breaching by an unauthorized

person. Not all of the countermeasures suggested in the following sections will be appropriate for every application, however. There is always the necessity of striking a suitable compromise position between the expense and inconvenience of a locking system and the value of the items it is designed to protect. Complex and expensive very high security systems are simply not appropriate for most residential applications. On the other hand, a cheap padlock on a warehouse containing valuable merchandise is an open invitation for someone to break in and steal it. The objective should always be to ensure reasonable protection in the circumstances surrounding a particular application. With locks, overprotection is often more harmful than insufficient protection. If the user is faced with a more complex security system than he thinks is really necessary, he simply won't use it. A great many unlawful entries are still made through *unlocked* doors and windows. The temptation to avoid the inconvenience of constantly locking and unlocking barriers seems to be insurmountable in some people. Contributing to this temptation by insisting on more protection than the user actually needs simply aggravates the problem.

SURREPTITIOUS ATTACKS

Four basic surreptitious approaches are used to breach locking devices: illicit keys, circumvention of the internal barriers of the lock, manipulation of the internal barriers, and shimming. The susceptibility of any locking device to these approaches cannot be eliminated, but can be minimized through the use of commonsense countermeasures.

Illicit Keys

The easiest way of gaining entry through any lock is by using the proper key for that lock. Thousands of keys are lost and stolen every year. If a potential intruder can determine which lock a lost or stolen key fits, he has a simple and quick means of illicit entry. If he can't get hold of the owner's key, quite often he can make a duplicate. The casual habit of leaving house keys on the key-ring when a car is left in a commercial parking lot or for

servicing provides a potential intruder with a golden opportunity to duplicate the house keys for later use. He can also find out the owner's address very quickly by examining the repair bill or tracing his automobile license number.

The risk of lost, stolen or duplicated keys cannot be eliminated entirely, but certain steps can be taken to minimize it.

Maintain Reasonable Key Security.

- Under some circumstances, it is almost impossible to avoid leaving at least the ignition key with a parked car, or one to be serviced. But all other keys should be removed.
- When keys are being duplicated, the owner should ensure that no extra duplicates are made.
- Many locks, particularly older locks, have their key code stamped on the front of the case or cylinder. This permits anyone to look up the code in a locksmith's manual and find the proper combination for that lock (or for that combination lock). Codebooks are readily available for most makes of lock, so if the code appears anywhere on the lock where it can be read after the lock is installed and locked, it should be removed by grinding or overstamping. If removal is not possible, the lock or its combination should be changed.
- Managers and owners of commercial enterprises should maintain strict control over master keys, and control keys for removable core cylinders. The loss of these keys can compromise the entire system necessitating an extensive and expensive, system-wide recombination. Too often in large institutions, just about everyone can justify a need for a master key. This is nothing more than a demand for convenience that subverts the requirements of good security. The distribution of master keys should be restricted to those who literally cannot function without them.

Since it is impossible to prevent people from losing keys no matter how careful they are, the next precaution is to *ensure that the lost key cannot be linked to the lock it operates.*

- The owner's name, address, telephone number, or car license number should never appear anywhere on his key ring. This has become common practice to ensure the return of lost

keys, but if they fall into the wrong hands, the address provides a quick link between the keys and the locks they fit. The proper protection against lost keys is to always have a duplicate set in a secure place.

- For the same reasons, keys which are stamped with information that identifies the location of the lock should not be carried around. This used to be a common practice on locker keys, safety deposit box keys and some apartment building keys. It is no longer as common as it once was, but it still exists. If the keys must be carried, all identifying information should be obliterated, or they should be duplicated on a clean, unmarked key blank.

Recombinate or Replace Compromised Locks. If all these precautions fail and the owner reasonably believes that someone has obtained keys to his locks, the combinations of these locks should be changed immediately. Where this is not possible, the locks may have to be replaced. When only a few locks are involved, recombinating cylinders is a fairly quick and inexpensive operation well within the competence of any qualified locksmith.

Another common attack method using a key against which there is less direct protection is the *try-out key*. Try-out key sets are a common locksmith's tool and can be purchased through locksmith supply houses, often by mail. These sets replicate the common variations used in the combination of a particular lock series. In operation, they are inserted into the lock one at a time until one is found that will operate the lock.

Try-out keys are commercially available only for automotive locks. There is nothing, however, to prevent a would-be intruder from building his own set for other locks. In areas where one contractor has built extensive residential and commercial developments, most of the buildings will often be fitted with the same lock series. If it is an inexpensive series with a limited number of useful combinations, a home-made try-out key set which replicates the common variations of this particular lock series could be very useful to the potential intruder.

The defense against try-out keys is simply to use a lock with a moderate to high number of available combinations. Any lock worth using has at least several thousand useful combinations. No intruder can carry that many try-out keys, so the risk that he will have the proper key is minimal.

Circumvention of the Internal Barriers of the Lock

This is a technique used to directly operate the bolt *completely bypassing* the locking mechanism which, generally, remains in the "locked" position throughout this operation. A long, thin, stiff tool is inserted into the keyway to bypass the internal barriers and reach the bolt assembly. The tool (often a piece of stiff wire) is then used to maneuver the bolt into the retracted, unlocked position. Warded locks are particularly vulnerable to this method (as was indicated earlier), but some tumbler mechanisms which have an open passageway from the keyway to the bolt assembly are also susceptible. Some older padlocks and cylindrical mechanisms had an open passageway of this sort. Few of these are manufactured anymore, but some of the older models are still in use. Any lock which has such an opening should be replaced with a better device if reasonable security is a requirement.

Manipulation

The term "manipulation" covers a large number of types of attacks. At least fifty discrete techniques of manipulating the mechanism of a lock without the proper key have been identified. Fortunately, however, they all fall rather neatly into four general categories. *Picking*, *impressioning*, *decoding* and *rapping*. Regardless of the specific technique used, its purpose is to maneuver the internal barriers of a tumbler mechanism into a position where they will permit the bolt to be retracted. In a disc pin tumbler mechanism, this means that the cylinder plug must be freed to rotate; in a lever lock, the levers must be aligned with the fence.

The basic countermeasures against all forms of manipulation are the use of close tolerances in the manufacture of the mechanism, and increasing the number of pins, discs, or levers. Close tolerances and a large number of tumblers make manipulation a time-consuming process. A number of specific defenses to the various forms of manipulation have also been developed. These will be presented in some detail below.

Picking. Lock picking is undoubtedly the best known method of manipulation. It requires skill developed by dedicated practice, the proper tools, time, and often a small dose of good luck. No

lock is proof against picking, but the high-security locks are so difficult to pick that it takes even an expert a long time to open them. One definition of a high-security mechanism, in fact, is one that cannot be picked by an expert in under one-half hour.

The techniques involved in picking the three basic types of tumbler mechanisms are very similar—so similar, in fact, that an example using the pin tumbler cylinder will serve to illustrate the rest.

All picking techniques depend on the slight clearances that must necessarily exist in a mechanism for it to function. The basic technique requires slight tension to be placed on the part of the mechanism that retracts the bolt (which is the cylinder plug in pin tumbler mechanisms) by a special tension tool designed for that purpose (Figure 3-1). The result of this tension is shown in Figure 3-2. The pin chamber in the plug has moved slightly out of alignment with the pin chamber in the cylinder shell, creating two "lips" at points (A) and (B). When the key pin is pushed up by the pick, it tends to catch at the shear line because the lip at point (A) permits it to go no farther. This pushes the driver above the shear line where the lip at point (B) prevents it from falling down into the cylinder plug once more. As long as tension is maintained, it will stay above the shear line.

This operation is facilitated by the fact that, as shown in Figure 3-3, the pin chambers in a cylinder plug are seldom in a perfectly straight line. Consequently, the pin closest to the direction of tension will be more tightly bound than the rest of the pins when tension is applied. It can easily be located because it will offer the most resistance to being maneuvered by the pick. Each pin is tested by lifting it with the pick. The pin that is most resistant is picked first. When this pin reaches the shear line, often the cylinder plug will move slightly. The picker receives two important benefits from this very small movement: first it tells him that the pin has indeed been lifted to the shear line, and second, the movement of the cylinder increases the misalignment between the pin chamber in the plug and the one in the shell, making it even less likely that the driver will drop down into the plug (Figure 3-4). Once this pin has been picked, the pin next nearest the direction of tension will be the most tightly bound. It is located and picked next. The cylinder plug will again move a very small amount. This operation continues until all of the pins are picked above the shear line, and the cylinder plug is free to rotate.

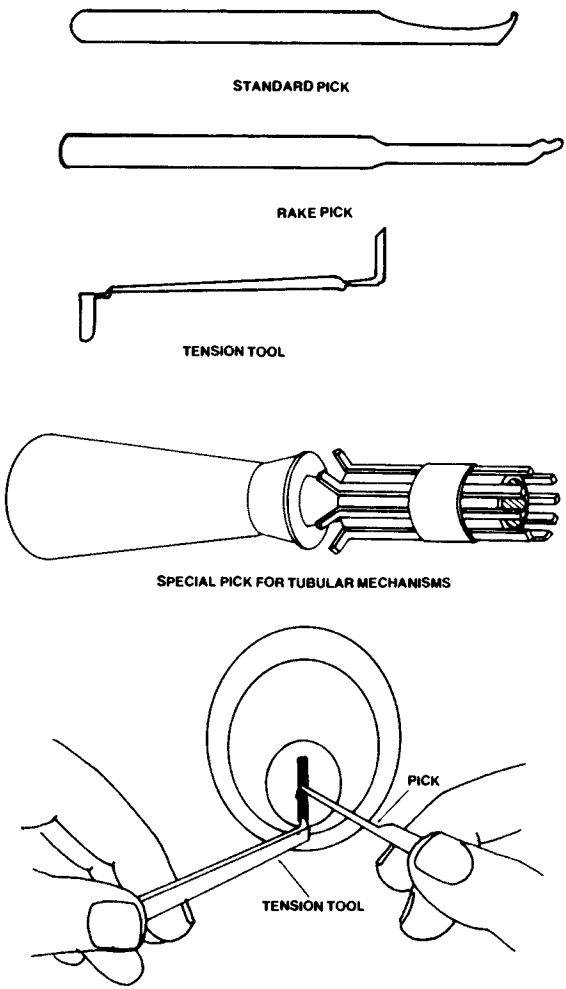


Figure 3-1. Lock picks.

There are endless variations of this basic picking technique. One of the most common is the use of a *rake pick* (Figure 3-1). When this pick is used, very slight tension is applied to the plug, then the rake is run along the tumblers lifting them slightly each time until all of them reach the shear line. Raking increases the chance that one or more key pins will inadvertently be pushed up into the cylinder shell—which will not allow the plug to rotate. It is often necessary to release the tension applied to the plug, and start over

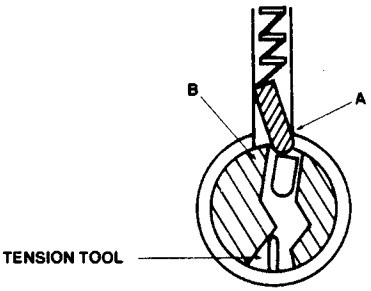


Figure 3-2. Illustration of the misalignment caused in a pin tumbler cylinder when tension is applied.

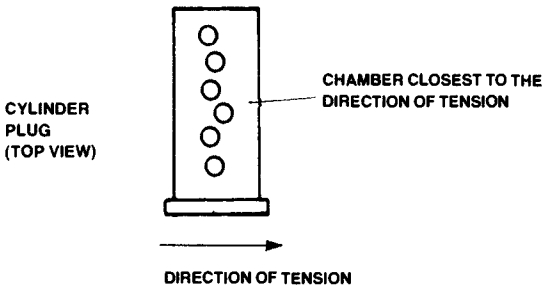


Figure 3-3. Pin chamber misalignment. Pin chambers on even the best cylinders are not in a perfectly straight line. The misalignment in this illustration is highly exaggerated for clarity.

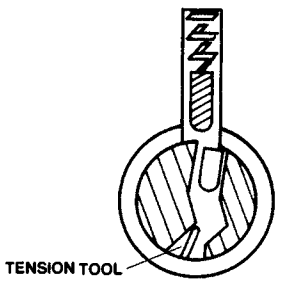


Figure 3-4. Increased misalignment occurs as each pin is picked.

again several times. Nevertheless, it is a very fast technique, and very popular. With luck, an expert can pick an average pin tumbler in a few seconds using a rake.

Most of the improvements in lock technology made over the last few thousand years have been devoted to increasing the resistance of locks to lock-picking. The major defense is the use of very close tolerances in the mechanism during manufacture. This makes the forced misalignment between the plug and shell necessary for successful picking more difficult to achieve. The addition of more tumblers is also some protection against picking, since it takes the operator more time to pick all of the tumblers in the mechanism. The Sargent Keso mechanism and the Duo disc tumbler use this basic approach. The twelve pins in the former, and fourteen (soon to be seventeen) discs in the high-security (U.L.) Duo take a reasonably long time to successfully pick. In addition, the unusual configurations of these tumblers make picking even more difficult.

The unusual arrangement of tumblers is also a basic security feature of Ace (tubular) mechanisms. These cannot be picked using ordinary picks. But there are special tools available which facilitate picking this lock (Figure 3-1). The Ace lock also requires special skills, but these are not too difficult to achieve once basic picking techniques have been mastered.

Modifications of pin design for increased resistance to picking (and other forms of manipulation) are becoming increasingly important as a basic means of precluding this form of attack. As shown in Figure 3-5, mushroom, spool and "huck" pins tend to bind in the pin chamber when tension is applied to the cylinder plug, preventing the key pin from reaching the shear line. The use of these pins does not provide an absolute defense against picking attempts, but a steady hand and a great deal of skill are required to pick them successfully.

Pins which must be rotated provide what is perhaps the maximum currently available protection against picking. The Medeco and the new Emhart interlocking mechanism both require pins to be lifted to the shear line *and* rotated to a certain position before the lock will operate. It is very, very difficult to rotate these pins into the correct position consistently. The interlocking pins on the Emhart also make it extremely difficult to pick the key pin to the shear line, since when interlocked, the two pins act as if they were one solid pin. The key pin and driver will not split at the shear line unless the pins are first rotated to the correct position.

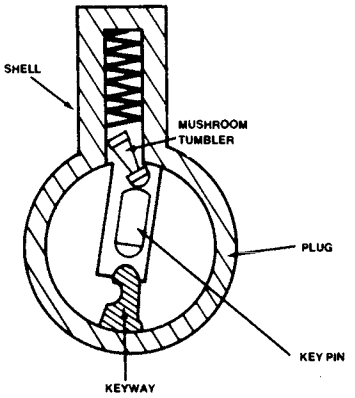


Figure 3-5. Mushroom and spool tumblers tend to bind in the pin hole when manipulation is attempted.

Fewer such embellishments are possible with discs and levers. Most high-security lever locks, however, do use levers which have a front edge cut in a saw-tooth design (serrated). These serrations tend to catch on the fence as it is pushed back to provide pressure on the levers. This often makes it necessary for the operator to release tension and start over again, increasing the time he must spend picking the lock. The use of two sets of levers with two corresponding fences also increases a lever mechanism's resistance to picking attempts.

Impressioning. Impressioning is a technique used to make a key that will operate the lock. It cannot ordinarily be used against high-security mechanisms, but against the average lock, it can be very successful.

To make a key by impressioning, a correct key blank is inserted into the lock. It is then securely gripped by a wrench or pliers (there are also special tools available for this purpose) and a strong rotational tension is applied to the plug. While this tension is applied, the key is moved up and down in the keyway. Since the tumblers are tightly bound in the lock by the tension applied to the plug, they will leave marks on the blank. The longest key pin will leave the strongest impression. The key is then removed and a slight cut is filed in the blank at this point. The top of the key is smoothed down with a file or abrasive paper, and the key is

again inserted to pick up the impression of the next longest pin. As long as the pin leaves an impression, the cut is deepened. When the pin will no longer leave a mark, the cut is at the right depth. When all of the cuts are to the right depth, the key will operate the lock and permit entry.

Certain types of lock mechanisms are more susceptible to impressioning than others. Warded locks are easily defeated by this method since the fixed wards can be made to leave strong impressions, and, as previously stated, the depth of the cut on a warded key is not critical. Lever locks are probably the most immune to this technique, since it is difficult to bind the levers in such a manner that they will leave true impressions on the key blank. The use of serrated levers greatly increases this difficulty.

The average pin and disc tumbler mechanism is vulnerable to this approach, but some of the better high-security mechanisms, because of their unusual keys, are not. The Medeco and Emhart interlocking mechanisms are highly resistant. The correct angles of the slant cuts necessary on these keys cannot be determined by impressioning. Modified spool and mushroom tumblers in any pin tumbler mechanism also tend to increase the difficulty of getting good impression marks.

Decoding. Another method of making a key for a particular lock is through decoding. It was mentioned earlier that most disc tumbler mechanisms can be "sight read" fairly easily. Sight reading involves the manipulation of the tumblers with a thin wire while noting their relative positions in the keyway. Since each mechanism has only a limited number of possible tumbler increments, the correct alignment of these increments can be estimated with fair accuracy permitting a key to be filed or cut on the spot to rotate the lock. This is one method of decoding.

A more common method is to insert a decoding tool or a specially marked key blank for a short distance into the keyway of a pin or disc tumbler mechanism. Using the key, rotational tension is applied to the plug which causes misalignment between the pin chambers in the plug and shell. The key is then slowly inserted into the keyway until it has forced the first tumbler to the shear line (Figure 3-6). The length of this first key pin is determined by the distance the blank (or special tool) enters the keyway. The blank is then moved to the second tumbler, and so

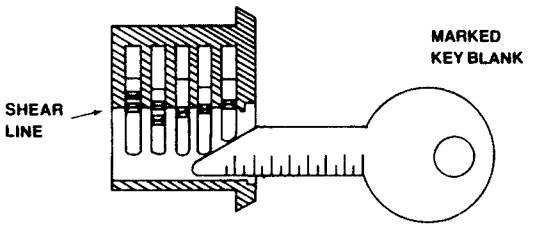


Figure 3-6. Decoding using a marked key blank.

on until the length of all of the tumblers is determined and a key can be cut.

Pin tumbler cylinders having wide tolerances are the mechanisms which are most susceptible to this particular decoding method. Disc tumblers are less so, although most can be easily sight read (the Duo, however, is very resistant to sight reading). Lever locks require special equipment to decode.

The special features offered on some high-security pin tumbler systems dramatically increase their resistance to this technique. Some are almost immune. The Ace can be decoded, but it usually requires special tools. The use of mushroom or spool tumblers in almost any mechanism increases its resistance to decoding. And, of course, the close tolerances of any of the better mechanisms are a basic defense against decoding as well as impressioning and picking.

Rapping. This approach relies on the fact that pins in a tumbler mechanism can move freely in the pin chambers. Tension is applied to the plug, resulting in the usual misalignment between the core and shell pin bores. The lock is then struck with a sharp tap just above the tumblers. This causes the pins to jump in their bores. As each key pin reaches its shear line, it pushes the driver before it into the shell where it tends to bind, unable to drop back down into the plug because of the lip caused by the misalignment. Not all of the drivers will be pushed over the shear line by one rap. Several may be required.

Theoretically, almost any lock may be defeated by rapping, but in practice it is a method that is used primarily on padlocks. Since padlocks are not encased in a door, they respond more freely to rapping. Modified, manipulation-resistant pins make

rapping very difficult, but not impossible. It is nevertheless, not a practical approach to high-security padlocks which use close tolerances and modified pins.

Shimming

Any part of a locking mechanism which relies on spring pressure to hold it in place is vulnerable to shimming unless it is protected. Spring-loaded latch bolts can be shimmed by a thin plastic or metal tool unless they are protected by anti-shim devices. The locking dogs in padlocks are susceptible to a shim inserted into the shackle hole. The shim acts to force the dog back against the spring pressure releasing the shackle (Figure 3-7). Padlocks which use heel and toe locking are more difficult to shim, but the safest course to use is a non-sprung, positive locking system which cannot be threatened by shimming at all.

FORCEFUL ATTACKS

If a potential intruder does not have the skills necessary to decode, impression or pick a lock, his only course is to either find a key, or use force against the lock to disable and breach it. Comparatively few intruders have developed manipulative skills, so it is not surprising that the large majority of attacks on locks employ force of one kind or another. Locks can be punched, hammered,

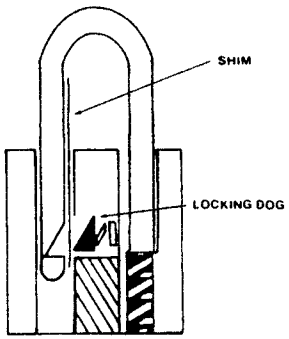


Figure 3-7. Shimming a padlock with spring-loaded locking dog.

wrenched, twisted, burned, pulled, cut, exploded and pried. Given the right tools and a sufficient amount of time, any lock can be defeated by force. But the nature of forceful attacks entails a number of real disadvantages to an intruder who is trying to gain entry without being discovered in the process. Large and cumbersome tools which are difficult to carry and conceal are often required. This is especially true if one of the better protected locks is being attacked. Secondly, forceful attacks usually make a considerable amount of noise. Noise, especially unusual noise, tends to prompt people to investigate. Third, it is always immediately evident to even a casual observer that the lock has been attacked. When surreptitious techniques are used, the lock can be opened without damage, and relocked, and no one will be able to tell that an unlawful entry has taken place. This often permits the intruder to thoroughly cover his tracks even before an investigation is started (if one is started at all).

The object of countermeasures against forceful attacks is to increase these hazards. Generally, more force will have to be applied to stronger, protected locks, requiring larger and more sophisticated tools, taking more time, making more noise, and leaving more evidence that the lock has been defeated.

While it is sometimes possible to wrench, pry, or pull an entire lock out of a door, most attacks are directed at either the bolt or the cylinder. If the bolt can be defeated, the door is open. If the cylinder can be defeated, the bolt can be maneuvered into an unlocked position. The more common of these attacks will be presented below along with measures that can be taken to strengthen a lock against them. It bears repeating that no lock is absolutely immune to forceful attacks. The object is to make its defeat more difficult, noisier, and more time consuming, thereby increasing the chances that an intruder will be detected or simply give up before he has successfully breached the lock.

Attacks on Bolts

Bolts can be pried, punched, and sawed. The object of these attacks is to disengage the bolt from the strike.

Jimmying and Prying. A "jimmy" is by definition a short prying tool used by burglars. It is a traditional and well-known burglar

tool. But other, more lawful, prying tools will work just as well if not better. These include: prybars, crowbars, nail pullers, and large screwdrivers.

The easiest prying attack is against latch bolts with anti-shim devices. A screwdriver or similar tool with a flat blade is inserted between the strike and latch bolt. Pressure is applied until the anti-shim mechanism inside the lock breaks. The latch is then easily pushed into the retracted position, and the door is open. A supplementary long-throw or interlocking deadbolt is the best defense against this attack. Non-interlocking, long-throw deadbolts are theoretically vulnerable to jimmying, but it takes a much larger tool, more time, and the destruction or spreading of part of the door jamb so that the end of the deadbolt can be reached with the prying tool. Even then, a great deal of force is required to push the bolt back into the lock and free the door. These combined disadvantages make direct jimmying attacks against long-throw deadbolts very impractical. They are even more impractical against interlocking deadbolts. If the lock and strike are properly installed, the whole strike would have to be pried loose. This would ordinarily entail the destruction of a considerable portion of the jamb around the strike.

A deadbolt can also be attacked indirectly by prying. An attempt is made to spread the door frame so that the bolt is no longer engaging the strike (Figure 3-8). An average man can apply about 600 in./lb. of force using a pry bar 30 inches long. This is usually more than enough to spread a door jamb to clear the normal one-half inch bolt, but a one inch (or longer) bolt is more difficult to clear. Interlocking bolts are almost impossible to defeat with this method since they, in effect, anchor the door to the door frame. In order to spread the frame, the entire strike would have to be pried out. A properly installed security strike is very difficult to remove. Interlocking deadbolts were designed to resist just this type of attack. By and large, they are successful. When properly installed, they are, as a practical matter, virtually immune.

Automobile bumper jacks (or similar tools) can also be used to spread a door jamb and release the bolt (Figure 3-9). Most American jacks are rated at one ton. It is probably safe to say that most wooden door frames will succumb to that much force. Reinforced metal frames are more resistant. Long-throw and interlocking deadbolts provide some protection. They may even

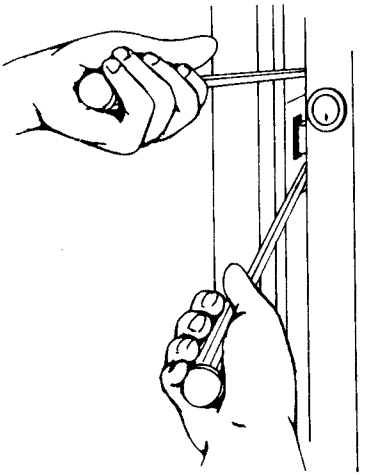


Figure 3-8. Jamb spreading by prying with two large screwdrivers.

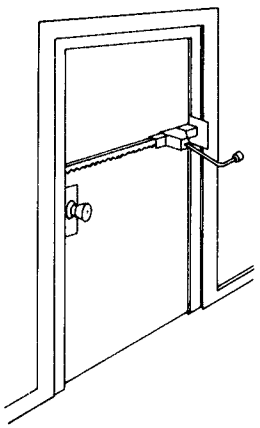


Figure 3-9. Use of an automobile bumper jack to spread the door frame. Standard bumper jacks are rated to 2000 pounds. The force of the jack can be applied between the two jambs of a door to spread them and overcome, by deflection, the length of the latch throw.

provide enough protection in most circumstances, since a jamb can only be spread so far by the jack before it buckles outward releasing the jack. The best defense against jamb spreading, however, is a properly constructed and reinforced door frame.

Fortunately, this type of attack is fairly rare. An automobile jack is an awkward tool, hard to carry and conceal, and it requires some time to set up and operate.

Punching. The California Crime Technological Research Foundation (CCTRF) identified punching as a possible direct attack on a deadbolt (Figure 3-10). The attacker would have to punch through the wall and framing members to reach the bolt. It would be fairly easy to miss the bolt on the first few tries. So several attempts may be necessary. In essence, the punch and hammer are used to force the bolt back into the body of the lock allowing it to clear the strike. CCTRF determined that an average man can apply a force of 125 in./lbs. with a one-pound hammer.

Most bolts will probably succumb to a determined punching attack. But it is a noisy approach, and rather hit or miss since it is somewhat difficult to tell if the punch is actually engaging the bolt, and the punch has a tendency to slip off the face of the bolt when it is struck. It might, therefore, take a considerable amount

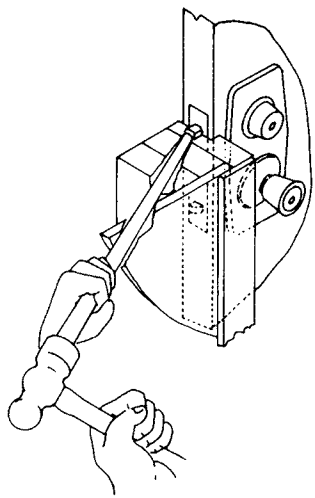


Figure 3-10. Forcing the deadbolt with a drift punch and hammer.

of time. The amount of time and the noise involved would probably be a serious disadvantage to an intruder, making this an attack of last resort.

Sawing. Bolts can be sawed by inserting a hacksaw or hacksaw blade between the face plate and the strike (a portion of the jamb will usually be removed or the jamb spread to allow easy access) (Figure 3-11). Better locks now use hardened bolts or hardened inserts inside the bolt to resist sawing. An even better defense are free-wheeling rollers placed inside the bolt. When the saw reaches these rollers, the sawing action rolls them back and forth, but will not cut them. Modified bolts are present in almost all relatively secure locks. They are virtually immune to sawing attacks.

Peeling. Another way to expose the bolt in metal-framed doors is by peeling. Thin sheet steel and aluminum can be easily peeled (Figure 3-12. The normal countermeasure against this attack is to use a reinforced strike. Peeling may also be used with prying in an attempt to force the bolt back into the lock.

Attacks on Cylinders

Like bolts, cylinders can be pried and punched. They can also be drilled, pulled, and wrenched or twisted. The usual objective of such attacks is to completely remove the cylinder from the lock. Once it has been removed, a tool can be inserted into the lock to quickly retract the bolt.

Cylinder Pulling. The tool usually used for cylinder pulling is a slam hammer or dent puller—a common automobile body shop tool ordinarily used to remove dents from car bodies. The hardened self-tapping screw at the end of the puller is screwed into the keyway as far as it will go. The hammer is then slammed back against the handle (Figure 3-13). More often than not, an unprotected cylinder will be yanked entirely out of the lock with one or two slams. CCTRF determined that 200 in./lbs. of force could be applied to a cylinder by a dent puller, using a 2½ lb. hammer having an 8-inch throw.

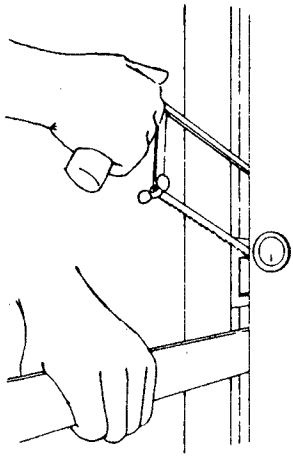


Figure 3-11. Sawing the bolt with a hacksaw.

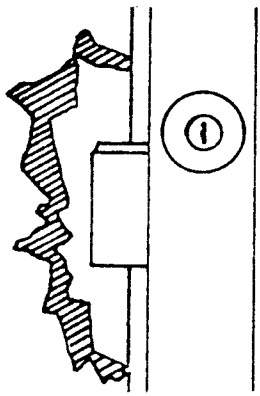


Figure 3-12. Jamb peeling to expose the bolt.

Many cylinders are vulnerable to this kind of attack because they are poorly anchored in the lock. Mortise cylinders, for example, are ordinarily threaded into the housing and held in place with a small set screw (Figure 2-7a). The threads are usually soft brass or cast iron. A good yank shears both these threads and the set screw.

Most tubular and rim cylinders are held in place by two (or more) bolts inserted from the rear of the lock (Figure 2-7b).

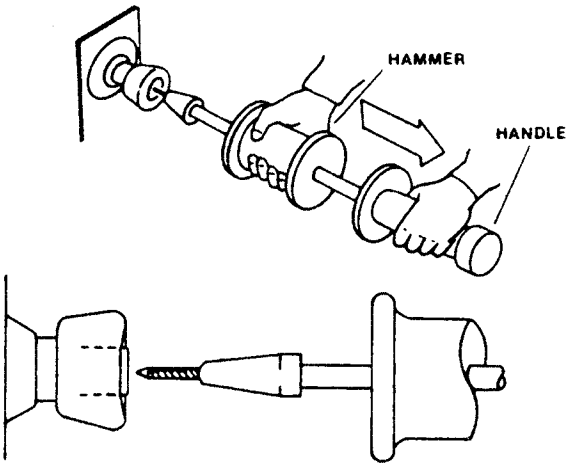


Figure 3-13. Cylinder pulling with a slam hammer.

This is a much more secure method of retaining the cylinder and one which resists pulling. Retaining bolts of at least ¼ inch in diameter made of hardened steel are good protection against most pulling attempts.

The threat of pulling can be significantly reduced by the addition of a cylinder guard. Some better lock assemblies are offered with built-in guards. Locks that do not have a built-in guard can be protected with a bolt-on guard. These are bolted over the cylinder using carriage bolts that extend completely through the door (Figure 3-14). They offer the maximum available resistance to pulling. The cylinder guard when correctly mounted cannot be pried off without virtually destroying the entire door.

Cylindrical (lock-in-knob) locksets are extremely vulnerable to pulling. Often the door knob will be pulled off with the cylinder exposing the entire internal mechanism to manipulation. There is no method of reinforcing a cylindrical lockset against the threat of pulling. The best measure is to replace it or add a good supplementary deadlock with a cylinder guard.

Plug Pulling. If the cylinder itself is protected against pulling, an attacker may turn to the cylinder plug. The plug is much harder to pull, and requires a special tool that looks something like a gear puller. A hardened self-tapping screw is engaged in the keyway and

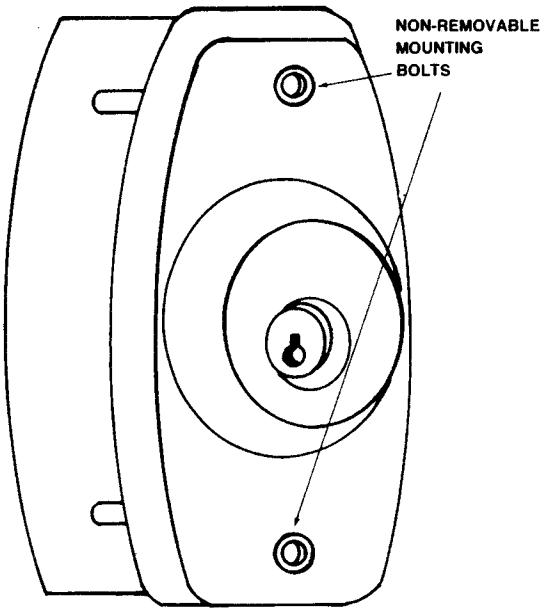


Figure 3-14. Bolt-on cylinder guard with backplate. This commercially available plate is of heavy aluminum and is mounted from the inside of the door with hardened steel bolts that enter threaded holes in the guard. It combines good protection with good appearance.

pressure is slowly exerted on the plug until the tumblers snap and the plug can be pulled from the cylinder shell. The bolt mechanism can then be operated by a tool inserted through the shell. The ordinary cylinder guard is no protection against this attack. A special guard is available, however, which is designed to prevent the plug from being pulled (see Figure 3-15).

Wrenching, Twisting and Nipping. Most cylinders project from the surface of the door sufficiently to be gripped by a pipe wrench or pliers. Twisting force is applied to the cylinder by the wrench which is often sufficient to snap or shear the set-screws or bolts that hold the cylinder in the lock. If the cylinder does not project enough for a wrench to be used, a ground down screwdriver can be inserted in the keyway and twisting force applied to the

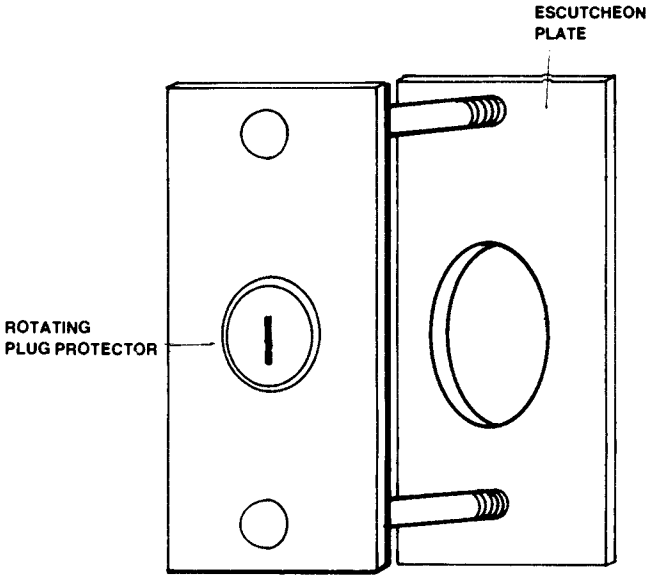


Figure 3-15. Cylinder guard with rotating plug protector.

screwdriver with a wrench (Figure 3-16). CCTRF found that a pipe wrench 18 inches in length could apply a maximum torque of 3,300 in./lb. to a protruding cylinder housing, and a screwdriver turned with a wrench could produce 600 in./lbs.

The proper protection against this threat once again is a cylinder guard. Some of the built-in guards are free-wheeling which prevents a twisting force from being successfully applied. Those that are not free-wheeling are still made of hardened steel which does not allow the wrench to get a good bite, but more importantly, prevents the wrench from reaching the actual cylinder. If a screwdriver and wrench are used, the cylinder might be twisted loose, but it cannot be pulled out. So although the lock might be damaged, it will not be defeated.

Bolt nippers can also be used to remove protruding cylinders by prying and pulling (Figure 3-17). Cylinder guards also forestall this type of attack.

Cylindrical locksets are very susceptible to wrenching, twisting and nipping attacks. Some of the better cylindrical devices have free-wheeling door knobs which provide some protection against

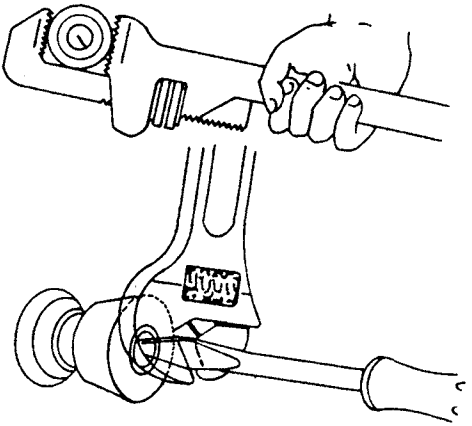


Figure 3-16. Removing cylinders by wrenching and twisting.

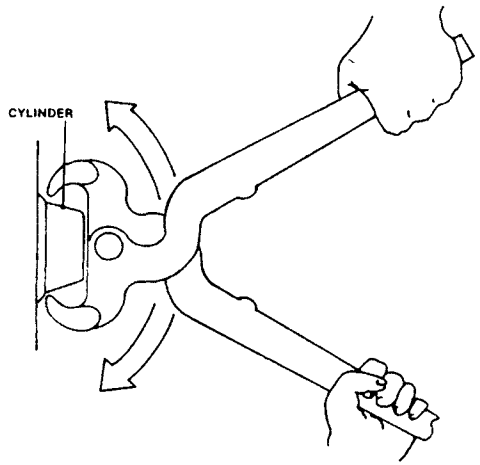


Figure 3-17. Cylinder removal with bolt nippers.

wrenching and twisting. Some incorporate break-away knobs which do not expose the internal mechanism of the lock when the knob is twisted off. Nevertheless, combinations of twisting, pulling, and hammering attacks usually quickly defeat these devices. The best remedy is to replace cylindrical mechanisms or supplement them with guarded deadlocks.

Drilling. Cylinder plugs can be drilled out using a fairly large drill bit. But the most common drilling attack is centered on the shear line between the plug and shell (Figure 3-18). A smaller bit is used to drill through the pins, creating a new shear line and releasing the plug which can then be rotated using a screwdriver or key blank in the keyway. Most of the better locks incorporate hardened inserts to frustrate drilling. Any lock receiving Underwriters' Laboratory's approval incorporates these features. Hardened materials do not prevent drilling, but drilling through tempered steel is a long and slow process which greatly increases the chances of detection.

Punching. Rim-mounted deadlocks are particularly vulnerable to punching. These are ordinarily mounted on the back of a door with wood screws. But, since most of the currently available doors are made with particle board cores under a thin veneer overlay, screws are seldom able to take much pressure. Several good blows with a hammer and punch on the face of the cylinder will often drive it through the door, pulling the screws out, so the entire lock body is dislodged.

Correctly mounting the lock using bolts which extend through the door and engage an escutcheon plate (or even large washers) on the front side generally frustrates punching attacks (Figure 2-5).

Cylindrical locksets are vulnerable to combination punching and hammering attacks. The knob is first broken off, then the spindle is punched through the lock, exposing the latch bolt assembly to manipulation.

Hammering. Hammering as well as pulling, wrenching and twisting is a quick and very effective way of disabling cylindrical

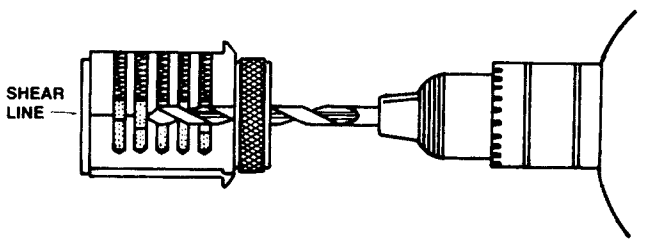


Figure 3-18. Drilling.

locksets. It is not as effective against cylinders, particularly those that are protected by cylinder guards. Ordinarily the knob on a cylindrical mechanism can be quickly broken off by one or two strong blows. There is no direct defense against this type of attack. Again, the only viable solution is a supplementary guarded deadlock, or replacement of the cylindrical lockset with a more secure lock.

4

Locks and the Systems Approach to Security

Locks are an essential part of most security systems. They are however, only one part. The effectiveness of a lock cannot be considered apart from the effectiveness of the entire system. A lock is no better than the door it is on, or the frame in which the door is mounted. The strongest lock available on a substandard door does not prevent the door from being defeated, even though the lock cannot be.

The degree of protection required from any security system reflects the value of the items to be protected. Most residences require only a modest degree of security—sufficient to thwart the casual or opportunistic intruder. Jewelry stores, banks and other establishments which must necessarily keep valuable items on the premises attract a more determined attacker. The degree of protection for these places must, therefore, necessarily be greater. But whatever the degree of protection required, the actual protection offered by any system is no greater than the

vulnerability of its weakest member. A good lock on a poor door provides no more protection than the strength of the door. A good lock on a solid door in a substandard wall is as vulnerable as the wall is weak.

The locks employed in any protection system must complement the system. If a moderate degree of security is required (as in a residential application), a good cylinder properly installed in a secure lock body must be correctly mounted on a good, solid door. The door itself must be correctly hung, using good hardware on a properly constructed door frame. The frame must be strongly braced, and secured to the wall. The wall itself must be at least as strong as the door system installed in it. If the lock, the door, the frame or the wall is significantly weaker than the rest of the system, it is the point most likely to be successfully attacked.

A good lock is essential to a good security system. It is often the point at which an intruder will focus his attack. But good locks are not synonymous with good security. Always examine the system as a whole.

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